Essays in Option Market Liquidity

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Abstract

This study investigates equity option market liquidity with different aspects of the bid-ask spread, open interest, and trading volume in the US. We find a newly discovered determinant of option liquidity: excess cash (that is, the level of cash reserve in excess of what can be captured by firm characteristics) after accounting for underlying stock liquidity. We display evidence that an increase of 1% in excess cash holding leads to a 0.58% reduction in option bid-ask spread, 0.28% increase in open interest, and 0.26% increase in trading volume. We also demonstrate that there is a significantly positive linkage between stock and equity option market liquidity. The results show that funding liquidity is a liquidity supplier of their market liquidity linkages. Stocks with a higher probability of informed trading or facing greater short-selling pressures register a significant reduction in the stock-equity option market liquidity interactions.

What is more, we analyse the effects of option market liquidity on stock price crash risk. We find that the magnitude of crash risk will increase when the companies with a higher trading volume and open interests of the options, while the option bid-ask spread will decrease market crashes.

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Chapter 1 Introduction

Market liquidity is defined as the ease of trading an asset (Jun *et al.*, 2003) which is crucial for the price discovery process[1] and financial market efficiency. The extant literature mainly investigated the determinants of market liquidity, such as underlying stock market performances, market makers' hedging and inventory costs, transaction costs, fragmented markets, financial regulatory restrictions, and funding constraints (Yang, 2018; Bernales *et al*., 2020). Recent studies have departed from these research directions and put emphasis on a new factor of market liquidity, which is the level of corporate cash holdings (Huang and Mazouz, 2018). Excess cash is the level of cash reserve in excess of that at the normal operating level, reflecting the companies' prospects and predicting stock returns (Simutin, 2010). Despite the growing theoretical guidance [2], there is limited empirical evidence to illustrate how excess cash affects market liquidity (Huang and Mazouz, 2018).

A part of my thesis is dedicated to the relation between excess cash and option market liquidity. Previous literature showed that excess cash is important because it captures a firm's future growth options (Simutin, 2010), reflects an enhanced investment capability and profitability (Mikkelson and Partch, 2003), as well as the ability to cushion firms from adverse future cashflow shortfall (Bates *et al.*, 2009). Furthermore, the importance of options market relies substantially on their characteristics, such as high liquidity, low transaction cost, high leverage, and the strong predictability of underlying stock returns (Black, 1975; Easley *et al*., 1998; Cremers and Weinbaum, 2010; Hayunga *et al*., 2012; Gharghori *et al*., 2017). Additionally, informed traders are more likely to trade in option markets due to these characteristics, which implies that options trading is more efficient when these traders have information privilege (Cao and Wei, 2010). In these option markets, we select data from the Option Metrics database, which supplies the historical data of price and quality, tools, and analytics. Furthermore, we employ

[1] Price discovery refers as the incorporation of new private information into the security price (Hasbrouck, 1995; Amin and Lee, 1997).

[2] Theoretically, a higher level of excess cash lessens adverse selection problems arising from the reduced uncertainty about firm valuations. Thus, it attracts uninformed traders and helps enhance market liquidity. In contrast, as the prospects of negative investment and more significant agency conflicts stockpiles excess cash, market liquidity decreases with larger excess cash when investors take these issues into account (Lin *et al*., 2009; Gopalan *et al*., 2012).

three proxies to account for option liquidity, including bid-ask spread, open interest, and trading volume (Chordia *et al*., 2000; Mayhew, 2002; Cao and Wei, 2010). As different dimensions of market liquidity are not easily incorporated into a single number, we use these three proxies to enhance our understanding in this research.

Our analysis is motivated by the previous research on corporate cash holdings. Following the extant literature, they systematically discussed the motives behind the firms holding excess cash in their saving accounts. The typical incentives include transactions motive, precautionary motive, and agency motive [3] (Jensen and Meckling, 1976; Jensen, 1986; Myers and Majluf, 1984). These motives lay the foundations of the theoretical arguments which identify firm-specific characteristics to determine corporate cash holdings (Opler *et al*., 1999). Generally, there are three theoretical arguments in determining the corporate cash holdings which are trade-off theory, pecking order theory and agency theory (Keynes, 1936; Myers and Majluf, 1984; Jensen, 1986; Opler *et al*., 1999; Ferreira and Vilela, 2004; Ferreira *et al*., 2005; Bigelli and Sánchez-Vidal, 2012; Gopalan *et al*., 2012; Anjum and Malik, 2013; Cruz, 2015).

For the above theories, trade-off theory deals with an optimal level of cash reserves that firms should maintain by balancing the costs and benefits of retaining extra cash (Ferreira *et al*., 2005; Anjum and Malik, 2013). The costs of cash holdings include the opportunity cost of capital invested in cash (Gao *et al*., 2013) and the agency costs arising from empire-building and managerial perks (Harford, 1999). Several benefits of cash holdings include minimizing the transaction costs associated with liquidating tangible or intangible assets, reducing the risk of experiencing financial distress and investing in the projects without severely hindered by financial constraint conditions (Pinkowitz *et al*., 2006).

[3] Regarding the transactions motive perspective, the transaction cost emerges when the firms convert their tangible or intangible assets to cash in response to the unpredictable events or pay for extra investment expenditure because of asymmetric information problem. Thus, it is crucial to the firms' reserve cash to minimize these transaction costs (Han and Qiu, 2007; Mahai and Radu, 2015). By preventing the capital market and preparing the potential adverse shock, firms will withhold extra cash from their account as a precautionary purpose (Gao *et al*., 2013; Kinnunen, 2015). More than that, firms should have sufficient cash holdings to avoid regret by not capturing the attractive investment opportunities (Pinkowitz *et al*., 2006). Due to the agency motive, entrenched managers incentivize to reserve cash either for their own sake at the expense of shareholders (Opler *et al*., 1999) or payout dividends payment with a lesser amount (Harford *et al*., 2008). Additionally, managers constrained by debt instruments tend to keep large cash reserves and reduce the level of committed credit (Sufi, 2009).

Contrary to the trade-off theory, pecking order theory indicated no optimal amount of cash that firms should retain (Opler *et al.*, 1999). The demand for internal financial resources causes firms to alter their level of cash holding (Myers and Majluf, 1984). The cash acts as the buffer and helps firms reduce the conflicts between retained earnings and investment needs (Ferreira and Vilela, 2004). Thus, cash reserves are the primary outcome after the firms make thorough corporate and financial investments assessments (Cruz, 2015). In the corporate finance view, 'companies prefer to finance their investments with retained earnings, then with debt and, lastly, with equity' (Bigelli and Sánchez-Vidal, 2012).

Regarding the agency theory perspective (Jensen, 1986), a manager has discretion on the corporation's cash holding policy. They tend to build excess cash balances to lessen the firm's liquidity risk, prepare financial distress, and strengthen their managerial discretion.

Based on these arguments related to the costs and benefits of holding cash, two different hypotheses with opposite outcomes are proposed to explain the association between excess cash and market liquidity. According to the pecking order theory, they supposed that larger excess cash reduces adverse selection problems due to the lower uncertainty in asset value (Gopalan *et al.*, 2012; Huang and Mazouz, 2018). Hence, firms withholding extra cash will attract uninformed traders and increase their market liquidity (Lin *et al.*, 2009; Gopalan *et al.*, 2012). In contrast, the agency theory contended that larger excess cash reduces asset market liquidity eventually. (Gopalan *et al.*, 2012; Huang and Mazouz, 2018). Because the negative investment prospects and a high degree of agency conflicts pile up excess cash, market liquidity declines with larger excess cash when investors are concerned about these issues.

Empirically, we examine the relationships between excess cash and equity option market liquidity over the period from January 2005 to August 2015. We show that excess cash significantly explains the liquidity of equity options. Trading volume and open interests of the options increase in companies with a higher magnitude of excess cash while the bid-ask spreads of equity options decline in excess cash. Our findings confirm the theoretical predictions by Gopalan *et al.* (2012) that excess cash improves market liquidity as it reduces adverse selection problems caused by the uncertainty in firm valuations. The relation between excess cash and option market liquidity becomes more pronounced for firms with a greater degree of informed trading or during periods of high volatility in financial markets. Our results also indicate that when the uncertainty about firms' prospects rises, excess cash becomes more valuable and affects option market liquidity.

Our research on excess cash and option market liquidity contributes to a large and growing body of literature on the association between corporate cash holdings and financial trading. The empirical findings reinforce the theories proposed by Gopalan *et al*. (2012), indicating that excess cash is significantly positive to option market liquidity. To the best of our knowledge, this is the first paper to show excess cash is a driving factor of equity option liquidity. It also provides a new direction for future empirical research expansion to derivatives markets. Furthermore, we contribute to the literature on how cash holding can benefit firms in the presence of investor sentiment. We use the ratio of put-to-call option traded volume to capture investor sentiment (Verousis *et al*., 2016b) [4]. This evidence is particularly apparent when option traders become more bearish [5]. Existing studies, such as Huang and Mazouz (2018), concentrated principally on the joint effect of financial performance indicators (e.g., financial constraints, firm values, and R&D expenses) and excess cash in stock market liquidity. Unlike these studies, we indicate that excess cash also influences option market liquidity through investor sentiment.

Additionally, our results have important implications for the market participants' decision making and financial regulators' policy implementation. Financial media highlighted the essential role of cash reserves during the coronavirus pandemic in 2020. For instance, Bank of England (2020) [6] stressed the corporate cash shortage results in a liquidity shortfall and thereby leads to financial instability. This kind of news also gives a political warning to regulators and addresses the problems at the outset. More than that, Bloomberg (2020) [7] showed that the

[4] A rise (fall) in the ratio means that more (less) put options being bought relative to call options. An increase in the ratio indicates that investors become bearish and are more likely to expect falling asset prices. Lower values of the ratio suggest that investors become bullish and tend to expect rising asset prices.
[5] The liquidity benefits of excess cash are evident from our investigations of the joint effect of excess cash and investor sentiment on option liquidity.
[6] See, for example, 'Financial Stability Report', Bank of England, August 2020.
[7] See, for example, 'Corporate America is Stockpiling Cash before Covid Winter Hits', Bloomberg, 11 Nov 2020.

connection between corporate cash reserves and devoted resources to understand its nature attract the market participants.

As excess cash is a common determinant of stock and option liquidity, we wonder whether there is an interaction between stock and option liquidity. Once establishing the relation between excess cash and option market liquidity, the second part of my thesis investigates the joint market liquidity dynamics of stocks and equity options. This relation is crucial because it has vital implications for cross-market trading and is crucial to understand whether a higher linkage of stock and equity option market liquidity may result in higher liquidity risk for investors. This investigation draws upon the dozens of theoretical literatures dealing with the interplay of option and stock market liquidity.

The literature on market liquidity linkages across multiple assets, such as equities and equity options, is related to funding theory, derivative hedge theory and option demand-based pricing theory. Based on the funding theory, funding liquidity is an essential source of multiple asset market liquidity linkages. Brunnermeier and Pedersen (2009) provided a theoretical framework and argued that traders with capital constraints cannot fully provide liquidity to the market. The causal effect will be established by relating the funding liquidity on market liquidity when aggregate traders lack capital resources because of these financial limitations. These financially constrained traders' failure reveals a causal effect of funding liquidity on market liquidity. The occurrence of a financial crisis will force the liquidity to withdraw. Consequently, enormous financial constraints and giant volatility risk will be incurred, thereby creating a disaster of asset fire-sale. Furthermore, funding risk and fire-sales effects lead to liquidity linkages across different asset markets (Marra, 2016). The empirical research presented the evidence in the equity and derivatives markets about this story (Comerton-Forde *et al*., 2010; Hameed *et al*., 2010; Ben-David *et al*., 2012; Jylha, 2018; Marra, 2016).

Regarding derivative hedge theory, both inventory risks and asymmetric information induce traders to engage in hedging activities, thereby enhancing stock and option market liquidity linkages (Huh *et al*., 2015; Li, 2016). Inventory carrying risk is a crucial determinant of stock-option liquidity interactions. Option bid-ask spreads are inversely linked to the hedging ability of market-making positions in the underlying market, estimated as the underlying stock liquidity.

When the liquidity of the underlying market increases, the bid-ask spread of derivatives declines, and the option liquidity increases. In addition, liquidity spillover effects from the underlying stocks to options depend heavily on the propensity to hedge in the underlying markets. Illiquid option market and high inventory risk facilitate the propensity to hedge in the underlying market, resulting in an enhanced liquidity spillover from the underlying stocks to equity options (Cho and Engle, 1999; Li, 2016).

Furthermore, asymmetric information is an important driving factor of stock-option liquidity interactions. As options trader has an informational privilege over stock traders [8], active hedging activities in the options market send informational signals to underlying stock traders. Equity traders enhance stock spreads to protects themselves against information risk, these will then further increase the hedging costs for options traders, and the option spreads. Consequently, hedging activities of options traders incurred from adverse selection risk in the underlying stock markets increase both stock and option spreads. In other words, they reinforce the option and equity market liquidity linkages (Biais and Hillon, 1994; Huh *et al*., 2015; Marra, 2016).

Based on the demand-based pricing theory (Garleanu *et al*., 2009), traders cannot perfectly hedge their positions. Thus, it is unavoidable that they will suffer demand pressures from the uncertainty contributed by the option unhedgeable part. In the quantitative aspect, the derivatives equilibrium price is computed as the function of demand pressure. This price will incentivize the utility-maximizing dealers to supply the exact number of options that the end-users demand. After accounting for hedging costs, the net option demand exerts an additive effect on the stock and option liquidity interactions. As stock markets are exposed to the risks of illiquidity and prices, so option market makers cannot hedge the exposure fully in the underlying stocks. Thus, the underlying stock price will exhibit an upward trend, and the costly short position requires higher option prices as compensation. Under the increasing price pressure, the derivative market illiquidity grows up. The reverse effects hold for the decreasing option values. (Korn *et al*., 2019).

[8] Informed traders are willing to trade in options markets due to option characteristics, such as high liquidity, low transaction cost, high leverage, and the strong predictability of underlying stock returns (Black, 1975; Easley *et al*., 1998; Cremers and Weinbaum, 2010; Hayunga *et al*., 2012; Gharghori *et al*., 2017).

Moreover, as the principal motive of option trading comes from private information, shocks to option illiquidity reflect option-induced demand pressures. Market makers who suspect information trading tend to aggressively increase stock illiquidity (Goyenko *et al*., 2015). In short, both inventory risk and adverse-selection risk increase trading costs and option demand pressure, thereby causing market liquidity linkages (Korn *et al***.**, 2019; Goyenko *et al***.**, 2015).

Building upon these three theories, we empirically examine the linkages of market liquidity between stocks and equity option markets from January 2004 to August 2015. We find that funding liquidity positively affects stock and option illiquidity. In addition, option market liquidity affects stock market liquidity positively and significantly, and vice versa. We contend that firm size and the degree of information asymmetry can explain these feedback effects. In other words, the larger companies exhibit lower linkages in market liquidity between stock and option markets. Furthermore, stocks with a higher probability of informed trading or facing greater short-selling pressures register a significant reduction in the interactions between stock and option market liquidity.

Our research on the market liquidity linkages of stock and equity options makes several contributions. For instance, we prove the time-varying linkages across underlying stock and equity option market liquidity and explain the existing sources of linkages. This empirical evidence helps to develop the micro-structure literature [9]. Additionally, our research enriches the empirical literature on the effect of funding liquidity on stock-equity option market liquidity.

To improve regulators' policymaking and traders' investment strategies, we attempt to introduce the methods of reducing the market risk via predicting or preventing liquidity dry ups. Furthermore, we closely monitor the relationship between different markets illiquidity transmission, especially when the markets are characterized by common fundamentals and hedging connections. More than that, we promote employing the more sophisticated risk

[9] O'Hara (1995) is the first study to define market microstructure as 'the study of the process and outcomes of exchanging assets under explicit trading rules'. Recently, 'National Bureau of Economic Research (NBER) defines market microstructure as a field of study that is devoted to theoretical, empirical, and experimental research on the economics of security markets. It includes the role of information in the price discovery process, the definition, measurement and control of liquidity, and transaction costs and their implication for efficiency, welfare, and regulation of alternate trading mechanisms and market structures' (Aigbovo and Isibor, 2017).

management tools to control the quantity of available capital for financial intermediaries and alleviate the impact of an overall market shock across multiple asset markets. Lastly but not least, we help traders and regulators understand the effects that new trading regulation and changes in (equity option) market structures may have on various asset markets.

This research not only discusses the relevant factors contributing to the option liquidity as above, but also contemplates the consequence of option market liquidity, such as stock price crash risk. Stock market crash risk is recognised as the extremely and suddenly negative firm-specific stock returns in the absence of large public and fundamental material news (Liu and Zhong, 2018). The negative information hoarding argument (namely, agency theory based on managerial incentives for hoarding bad news) is the most prevalent theoretical argument of its formation mechanisms (Bhatia, *et al*., 2014; Habib *et al*., 2018). In their argumentations, asymmetric information problems between corporate insiders and external stakeholders are the major driving factors of crash risk (Jin and Myers, 2006). Managers posit in advantageous positions to gather and release bad news. By exploiting their privilege, managers will hide as much bad news as possible to pursue a better career and compensation (Kothari *et al*., 2009). The accumulated bad information sustains the accelerated price inflation and fuels the bubble. However, their bad news holding ability is constrained by the costs of information hiding behaviour. When reaching the threshold, the negative news will release to the market at once and force investors to reassess their expectations of firms' prospects. Consequently, inflated share prices return to their true values, which lead to considerable stock price decreases, and this is what called stock price crash risk.

Furthermore, we present two theories explaining the linkage of market liquidity and stock price crash risk, which are governance theory and short-termism theory. Regarding the governance theory, the blockholders perform the function to alleviate the managerial myopia arising from the agency problems, such as the separation of ownership and control (Rubin, 2007; Boehmer and Kelley, 2009). In general, there are two major corporate governance mechanisms, which are intervention and exit (Hirschman, 1970). Corporate interventions promote strategic changes in different ways, such as public shareholder proposals, private letters to management, and voting against directors (Edmans, 2009). Blockholder exist indicates that blockholders sell their shares and the subsequent decreasing stock price ex-post tends to punish managers who damage business valuation. In the ex-ante scenario, managers are threatened by the potential blockholders' exit and make every effort to maximise firm value (Parrino *et al.*, 2003). Regarding short-termism theory, managerial short-termism is defined as the 'desire to achieve a high stock price by inflating current earnings at the expense of long-term growth' (Stein, 1989). Investors with both short-term investment horizons and concentrating excessively on the short-term performance are indeed transient investors (Porter, 1992; Fang *et al.*, 2014).

Because of the presence of transient investors, managerial myopia problems will be exacerbated. However, not all investors are alike in fact (Kang and Kim, 2017). For instance, dedicated traders have long-term investment horizons while transient traders have short time horizons (Bushee, 1998). From information production efficiency perspectives, dedicated managers' decision making can reduce market frictions via information production and the proportion of informed trade.

We combine bad news hoarding theory, governance theory and short-termism theory to propose opposite hypotheses regarding the effects of market liquidity on stock price crash risk. Consistent with the corporate government (external monitoring mechanism) and information production efficiency perspectives, market liquidity adversely affects crash risk by limiting managers' adverse information hoarding activities (Edmans, 2009; Holden *et al*., 2014). According to the external monitoring mechanism, market liquidity is benefited by blockholders' governance through building block and earning trading gains from intervention (Edmans, 2014). A higher level of market liquidity encourages the blockholders' supervision on firm management and curbs managerial bad news holding activities, thereby reducing stock price crash risk (Maug, 1998; Edmans, 2009). In the aspect of information production efficiency, higher market liquidity increases the information synthesis and the proportion of informed trade, thus these enhance the greater price informativeness about the fundamentals of corporate economics. In this situation, the ability of managers to accumulate negative information in the long term will constraint substantially, thus lowering the crash risk (Holmstrom and Tirole, 1993; Holden et al., 2014).

In contrast, the short-termism theory and governance theory (blockholder exit mechanism) argued that market liquidity increases crash risk due to a large amount of irrational investment from transient investors as well as the selling pressure from the large blockholder exit (Edmans, 2009; Bhatia *et al*., 2014). Short-termism theory (Porter, 1992; Fang *et al*., 2014) indicates that low transaction costs improve market liquidity and attract more transient institutional traders. Managers may cover negative information to boost short-term earnings when they cope with the downward pressure exerted by transient traders on the stock price. When concealed negative information is accumulated continually and beyond the threshold level, managers must reveal this information publicly. As a result, these transient investors will undergo 'cutting-and running' selling and therefore generates crashes. What is more, when the unfavourable information discloses publicly, higher market liquidity can promote blockholder exit. This huge selling pressure exerted by blockholders amplifies the market reaction to the firm-specific bad news, resulting in greater stock price crash risk.

In the empirical analysis, we show the positive relationship between US equity option market liquidity and stock price crash risk during the period between January 2000 and August 2015. The magnitude of crash risk will escalate in the companies with higher trading volumes and open interests of the options. Option bid-ask spread will decrease market crash risk. This relation is more pronounced for firms with a greater extent of informed trading, larger short interests, and options trader sentiment or during periods of high volatility in financial markets.

Both the global financial crisis and the Covid-19 pandemic emphasize the importance of further studies on stock price crash risk (Vo, 2020; Mazur *et al*., 2021). Our research makes several academic contributions. First, we introduce option market liquidity as a potential determining factor of crash risk and contribute to the research in the crash risk topic (Bhatia *et al*., 2014; Liu and Zhong, 2018; Liu *et al*., 2019). Secondly, we associate firm-specific option trader sentiment with crash risk. To the best of my knowledge, this is the first empirical paper to analyse how equity option liquidity contributes towards the crash risk in the underlying equity market.

Furthermore, understanding the distribution of extreme return helps investors improve portfolio diversification and arrange effective risk management strategies (Chauhan *et al*., 2017). In addition, regulators and policymakers can further understand the economic implications of certain policies. Nevertheless, the government should develop corrective action after the lectures of the occurrence of extremely catastrophic events (Kim *et al*., 2011b). Our paper presents a new channel to reduce and even prevent extreme stock declines via equity option liquidity and thereby help investors in allocating capital resources to less risky businesses (Habib and Hasan, 2017).

To summarize, there are three main parts of Chapter 1, which are the aim and scope of thesis, the motivations and justifications for thesis, and thesis structure.

1.1 Aim and Scope of the Thesis

This study is developed by drawing on and uniting contributions from different theories, including corporate finance, behavioural finance, and microstructure economics. Due to the unique option characteristics relative to underlying equity, such as high liquidity, low transaction cost, high leverage, the strong predictability of underlying stock returns, and informed investors' preference, the current investigation targets American equity option liquidity concerning its influential factors and consequences. First, we started with the principal claim ‘Excess cash is a newly discovered factor of equity option liquidity’. As excess cash is a common determinant of stock and option liquidity (Huang and Mazouz, 2018), we then raised a question ‘Is there a relationship between stock and option liquidity?’. We found that stock and option liquidity is positively linked. Afterwards, we shift our attention from influential factors to a financial consequence of option liquidity: stock price crash risk. In all, at the heart of the research agenda is a desire to understand better different factors that drive option liquidity, and hence, how option liquidity affects stock price crash risk.

1.2 Motivations and Justifications for the Thesis

Equity options have endured as an essential instrument for the purpose of investment and risk management. According to The World Federation of Exchanges (2019), equity options become the most actively traded equity derivatives product, constituting up above 32 percent of the total equity derivatives trading volume. Options Clearing Corporation [10] also reports that recent years

[10] The Options Clearing Corp (www.theocc.com /Market-Data) and *Wall Street Journal,* Jul 24 2020.

witness considerable growth in the trading volume of equity options, because the daily trading volume almost doubles from fewer than 15 million contracts in 2015 to greater than 28 million contracts in 2020. Furthermore, equity options are popular owing to the reasons that the option markets allow high leverage, facilitate high level of trading volume, and exploit the predictive information about the underlying stock prices embedded in option prices. Uninformed investors, including retail investors, acknowledge their information disadvantages when trading against traders with informational privileges. They usually tilt their portfolio away from assets exposed to the greater information asymmetric risk, and consequently, this portfolio choice influences the liquidity of these assets (Ding and Hou, 2015).

Much effort has been devoted to studying the influential factors of option market liquidity, such as the underlying equity liquidity, inventory risk, information asymmetry, insider trading, and investor sentiment. However, excess cash, which is defined as the level of cash reserve in excess of that at the normal operating level, has never been thoroughly probed. Our investigation is motivated by the literature that focuses on the information content of corporate cash reserves. The level of cash reserve in excess of what can be explained by firm characteristics incorporates useful information about the companies' prospects and has strong predictability of stock returns (Simutin, 2010). Excess cash plays a vital role in option liquidity because it captures a firm's growth options (Simutin, 2010), reflecting higher investability and profitability (Mikkelson and Partch, 2003) to cushion firms from the exposure of adverse future cashflow shortfall (Bates *et al.*, 2009).

We demonstrated that excess cash is a newly discovered determinant of option liquidity, because larger excess cash reduces the uncertainty in asset value and then lessens adverse selection problems. Thus, firms with extra cash attract uninformed traders and enhance their market liquidity. Furthermore, excess cash also affects option liquidity through option investor sentiment. However, as Huang and Mazouz (2018) found that excess cash also acts as an accelerator in stock liquidity, we raised a question about whether there is a relationship between equity option and underlying equity liquidity. If this hypothesis is true, we have to control stock liquidity to reduce endogeneity in the investigation of excess cash and equity option liquidity.

Hence, the primary purpose of the second study is to examine stock and option market liquidity linkages and explain the existing sources of these linkages.

We found that there is a positive linkage between option liquidity and stock liquidity. Funding liquidity is a driving factor of their liquidity linkages (Brunnermeier and Pedersen, 2009). In addition, firm size, short sales and asymmetric information also contribute to these feedback effects. To put it another way, lower stock-option liquidity linkages occur in the larger companies. Stocks with a higher probability of informed trading or under the pressures from greater short selling experience a significant decrease in the interactions between stock and option market liquidity. The investigation of stock and option market liquidity linkages helps traders and regulators understand how new trading regulations and changes in (equity option) market structures affect various asset markets.

We not only discussed the contributing factors of equity option liquidity as above, but also contemplated the consequence of option liquidity in underlying equity markets, such as stock price crash risk. A more profound grasp of the distribution of extreme returns benefits investors to build a diversified investment portfolio and create risk management plans (Chauhan *et al*., 2017). Additionally, the lectures on extremely catastrophic events help the government develop corrective actions (Kim *et al*., 2011b). Empirically, we found a positive relationship between American equity option market liquidity and stock price crash risk. The magnitude of crash risk will escalate when the companies experience higher trading volumes and open interests of the options, and lower option bid-ask spread. Furthermore, we associate firm-specific option trader sentiment with crash risk. It introduces a new sophisticated risk management tool to increase option liquidity which can alleviate the stock price crash risk.

1.3 Thesis Structure

The thesis investigates equity option market liquidity and focuses on excess cash, the linkage between stock and equity option market liquidity, and the stock market crash risk. The structure of my thesis is as follows:

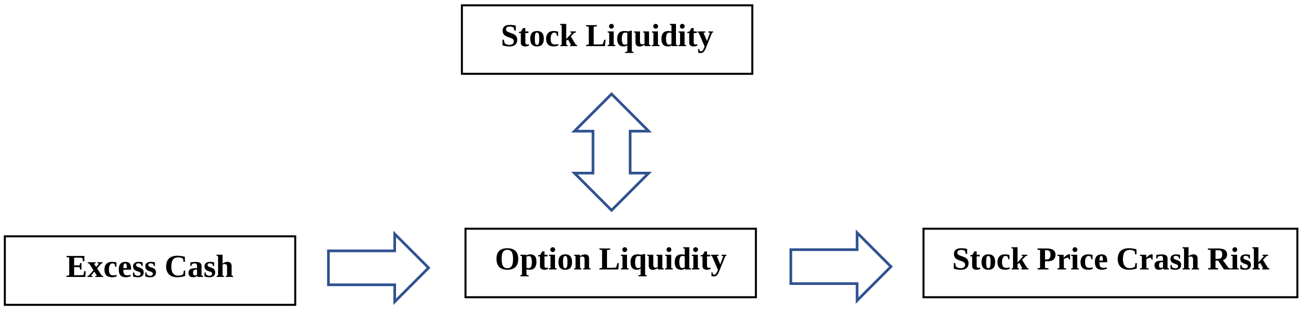


Figure 1.1 Thesis Structure

The thesis is organized as follows. Chapter 2 presents the motivation of options trading. Chapter 3 describes the theoretical arguments of corporate cash holdings and presents hypotheses of excess cash and option market liquidity. Chapter 4 explains the funding, hedging and option-induced demand channels of stock and equity option liquidity linkages. Chapter 5 describes the theoretical arguments of stock price crash risk and presents hypotheses of option liquidity and stock price crash risk. Chapter 6 describes data. Chapter 7 documents that excess cash positively affects option market liquidity. Chapter 8 shows the positive relationship between stock and option market liquidity and investigates their recourses. Chapter 9 finds the positive effects of option liquidity on stock price crash risk. Chapter 10 makes a conclusion. Chapter 11 lists references.

Chapter 2 Background Information: The Motivation of Option Trading

Options trading is an important component of market activities. In the 2010 Chicago Board Options Exchange (namely, CBOE) report, 54 million transactions and 1.12 billion contracts for a total dollar volume of $600 billion were recorded in the option market (Choy and Wei, 2012). However, sizeable option volume does not accord with option pricing theory, indicating that option volume is indeterminate in the complete market. In this theory, replication strategies show that option payoff can be replicated by a portfolio consisting of the underlying stock and a risk-free bond with the same value and payoffs in one period (Hull, 2003).

The main reasons behind large option volumes are related to transaction costs arising from the option liquidity and option leverage (Hayunga *et al*., 2012), and this is based on the theoretical model of information-based trading in option markets (Easley *et al*., 1998). One obvious explanation is that achieving perfect replication of options is prevented by transaction costs (Choy and Wei, 2012). The incorporation of transaction costs into option value causes unbounded costs (Leland, 1985; Whalley, 2011). As option market is liquid, transaction costs of options are lower than those of stocks and make it easy to hide informed investors' information (Easley *et al*., 1998; Gharghori *et al*., 2017).

Another reason is about option leverage (Black, 1975). Because option costs are lower than stock costs, an option provides a source of leverage that allows traders to control a larger option position than holding shares. Contrary to stocks, options bring leveraged payoff and provide different leverage exposures. When investors are optimistic about the future stock return, they will build highly leveraged positions in the option market to realize profit maximization. Generally, informed investors, such as mutual fund or hedge fund managers, are more sophisticated than uninformed investors and raise more concerns about leverage. As the manipulations of uninformed investors involve pushing stock prices out of fundamental value and preventing arbitrage, these investors will impose greater risk (De Long *et al*., 1990; Shleifer and Vishny, 1997). As a result, informed traders will create a relatively low leverage position in the option market (Hayunga *et al*., 2012), which is evident by the averaged leverage ratio of a hedge fund which is about 2 (Ang *et al*., 2011). In the theoretical perspective, due to the higher option liquidity relative to stocks and the advantage of option leverage other than stocks, informed traders prefer to trade in option market over stock markets.

Additionally, several reasons, such as the absence of uptick rule, low borrowing rate and margin requirements, attract investors to engage in derivatives markets. No uptick rule [11] is established to govern the short sales of options. Taking a short position by trading options is easier than shorting underlying stocks (Choy and Wei, 2012). Compared with the stock market, traders may achieve favourable implicit rates of borrowing and benefit from lower margin requirements in the option market (Hitzemann *et al*., 2018).

On the empirical side, options trading plays a vital role in price discovery. For instance, trading activities in option markets grow by over 10% in the four days before quarterly earnings announcements. Mid-quote returns to active-side option trades exhibit positively in the period without announcement and have a considerable upward trend prior to announcements. The wider option bid-ask spread is also observed during the announcement period (Amin and Lee, 1997). In addition, the volume imbalances of call options are significantly connected with stock returns in the subsequent day. The takeover target with the largest increase in call imbalance before the takeover announcement experiences the highest returns on the announcement day (Cao *et al.*, 2005). More convincingly, stocks with low put-call option volume ratios perform better than stocks with high ratios by over 40 basis points on the next day and around 1% over the next week (Pan and Poteshman, 2006). Furthermore, information about stock returns over the next few months is incorporated with option opening trades (Chan *et al*., 2010). Therefore, options trading embeds private information about future share prices.

In contrast, the opposite conclusion of information-based options trading can be found in serval empirical studies (Choy and Wei, 2012). Blau and Wade (2013) showed that options trades are less informative about future stock returns than short-selling ratios in respect of future stock returns. According to the theoretical argument of informed short sellers' migration from stock market to options market with tightened short-sale constraints (Diamond and Verrecchia, 1987;

[11] SEC Rule 10a-1 imposes on the exchanges an 'uptick' rule. Short sales should be executed at a price not below the preceding transaction price (Danielsen and Sorescu, 2001; Chen and Rhee, 2010).

Danielsen and Sorescu, 2001), it indicated that the underperformance of stocks with high short ratios is about four times larger than those with high put-call ratios. Although stocks with binding short-selling restrictions perform worse than those affected by put option activity, short selling contains more information about future stock prices. Proposed by Muravyev *et al*. (2013), due to no intermediate response of adjusted option quotes to options trading that may provide information, incremental information about stock quotes is not included in options quotes. 'We identify disagreement events only when the actual bid-ask range of the stock does not overlap with the option-implied bid-ask range, and we require that the difference between the closest points of the bid-ask ranges equals or exceeds a threshold' (Muravyev *et al*., 2013). In fact, stock price movements lead to disagreement events [12] and reflect useful information about the financial market function. These events only exhibit signed option volume in the direction that has a propensity to eliminate the disagreements but not display any signed stock volume. Thus, economically significant information about future stock prices is not incorporated in option price quotes but current stock prices.

As empirical studies on the information trading in the option market provide inconclusive results, the main cause of options trading is not determined. A theoretical model proposed by Cao and Ou-Yang (2009) demonstrated the stock and option trading based on opinion dispersion. It indicates that options trading is concentrated at a time of increased opinion dispersion while stock trading is diffuse. According to this theory, Choy and Wei (2012) concluded that options trading in terms of option volume is primarily caused by opinion dispersion. Firstly, most speculative options trading around earnings announcement is dominated by small retail investors. Secondly, considering the earnings announcement, the abnormal option turnover before the announcement can be used to predict the abnormal stock returns after the announcement. However, once controlling for the stock returns before the announcement, this predictability will disappear entirely. This evidence may mean that option investors turn to have speculative trading in options after taking cues from stocks. Lastly, opinion dispersion explains options trading significantly in both cross-section and time-series analyses. Thus, informed trading exists in stocks but not in options.

[12] 'We identify disagreement events in which the stock prices implied by the option price quotes are inconsistent with the actual stock price quotes' (Muravyev *et al*., 2013).

Apart from opinion dispersion (Choy and Wei, 2012), recent studies point out another determinant of options trading: the trading of retail investors (Boyer and Vorkink, 2014; Byun and Kim, 2016). Retail investors are defined as noise traders who behave in a less sophisticated manner than institutional investors and have a high likelihood of mis-reaction (Doran *et al*., 2013; Dimpfl and Jank, 2016). Investors' attention services as a necessary condition for stock prices to capture the full extent of public information, arising from the awareness of the information before analysing and reacting in some theoretical studies of asset pricing (Hirshleifer and Teoh, 2003; Hou *et al*., 2009; Hirshleifer *et al.*, 2011). Consistent with this theoretical argument, when retail investors select stocks, they prone to put the information about the different aspects of the company (e.g., history, product, environment, and strategies) into consideration (Barber and Odean, 2008). However, due to the limitation of human information processing ability, investors are inclined to choose their familiar and interesting stocks by using fewer mental resources. By doing these ways, investors will be only aware of these stocks and lead to subsequent stock trading (Ding and Hou, 2015). The retail investors also trade in different suboptimal ways, including the disposition effect [13] (Odean 1998), excess trading (Barber and Odean 2001), and overinvestment in glamour stocks (Titman *et al*. 2004). Based on behavioural finance models, noise trading causes temporal mispricing and higher volatility in the stock market (Black, 1986; De Long et al., 1990). In addition, retail investors' overreaction to call-put implied volatility spreads leads to call option mispricing (Shefrin and Statman, 2000; Doran *et al*., 2013). In similar, agent-based models of stock market volatility are proposed to show that noise trading acts as a driving force of additional stock volatility (Lux and Marchesi, 1999; Alfarano and Lux, 2007). The fundamental shock of volatility generates noise trading, which will increase volatility in turn.

Retail investors also trade in stock markets. They have a taste for stocks with lottery-like features, including low price, high variance, and large right skewness (Broman,2016). For the low-cost lottery tickets, the probability of obtaining a huge reward is faint, while the probability of a small loss is large, in which the probability of winning and losing is determined in advance. As with lotteries, these investors who search for 'cheap bets' are prone to invest in cheap stocks.

[13] Disposition effect indicates that assets that have won in the past will be undervalued and those that have lost in the past overvalued (Odean 1998).

As high idiosyncratic volatility is a strong predictor of estimated idiosyncratic skewness, cheap stocks with high skewness are perceived as lotteries, implying the high likelihood of realizing the extreme return events investors observed in the past again (Kumar and Page, 2014). In Gao and Lin (2015), jackpots [14] causes the trading volume of lottery-like stocks to decreases by 6.8% to 8.6%. In addition, large jackpots also decrease stock liquidity. The evidence is shown as an increase in the bid-ask spread. Thus, retail investors have a gambling preference for stocks.

Mounting studies found that retail investors have inclined to make gambling-induced stock investment decisions (Boyer *et al*., 2010; Eraker and Ready, 2015), but less focused on the lottery-type option preference (Byun and Kim, 2016). As with stocks, equity options provide ways for skewed payoff distributions and are deemed as lottery-like assets. Option markets offer investors additional gambling venues (Gao and Lin, 2015). Retail investors prefer large positive skewness (Barber and Odean, 2008; Kumar, 2009) and are attractive to high option leverage. Options with high leverage, which have lottery-like characteristics and low cost, but rarely achieve extremely high returns, fulfil the retail investors' appetite for gambling (Boyer and Vorkink, 2014). The following part will further investigate how retail investors trade in option markets.

The nonlinear option's payoff structure and implicit leverage characteristics amplify the underlying stocks' lottery-like characteristics and make return distributions more dramatically lottery-like. If enhanced lottery-like features of an option contract are acknowledged and utilized by investors with the preference for lottery, their gambling preferences will have a significant effect on option market (Boyer and Vorkink, 2014). As large jackpots are linked to a decline in options trading, which is highly sensitive to volatility, the substitution between lottery participation and option trading is empirical evidence to prove that investors' desire to gamble is one of the main reasons why they choose to trade in option markets (Gao and Lin, 2015). Byun and Kim (2016) also demonstrated the linkage between option returns and the lottery-like characteristics of underlying stocks. The monthly return of call options written on the most

[14] Jackpots are the cumulated lottery prize in excess of 500 million Taiwan dollars, which only happen after a series of no winners (Gao and Lin, 2015)

lottery-like stocks is much lower than similar call options written on the least lottery-like stocks by 10% to 20%.

Some studies raise concerns about the investors' gambling preferences in the option market. For instance, the unique characteristics of an option contract and different investment strategies reduce the effect of retail investors' gambling preferences on the option market to some extent. Lottery-like retail investors are disfavour of the complex and unfamiliar structure of options and less willing to participate in the options market than in the stock market. Their limited participation may reduce the influence of gambling preference on the option market (Byun and Kim, 2016). More than that, stock and option markets' segmentations cause the differences of marginal investors across two markets. Option traders have the analyses of the put-call parity relation so that they are more 'rational' than equity traders (Ofek *et al*., 2004).

Nevertheless, option returns, and disposition effects are affected by the lottery-like characteristics of underlying stocks. Byun and Kim (2016) showed that if underlying stocks have more lottery-like characteristics, options are more likely to deviate from the put-call parity in the direction caused by the overvaluation of a call option. What is more, the relationship becomes stronger for out-of-moneyness options, especially in the period of high investor sentiment. Gambling preference induced by investor optimism leads to the overvaluation of lottery-like options. Bergsma *et al*. (2020) also investigated whether the equity option investors' behavioural bias of the disposition effect is present in U.S. Option capital gains overhang (hereafter OCGO) proxies for unrealized gains/losses in the aggregate option market, which is used to describe the disposition effect. The close relationship between OCGO and option returns shows 'a deviation from the general pattern for extreme losses and gains', which implies that investors' disposition to trade the highest and lowest securities in their option portfolios in different ways (Bergsma *et al*., 2020). Furthermore, option open interest declines when OCGO rises.

Overall, both informed and uninformed investors have incentives to engage in options trading activities. Mounting theoretical and empirical studies support that low option transaction cost and the advantage of option leverage are attractive to informed investors. Yet, some empirical studies have mixed results and turn to support the roles of opinion dispersion and retail investors in options trading. It is expected that stock and equity option markets are closely linked.

Chapter 3 Data and Descriptive Statistics

According to the literature mentioned above, stock and equity option datasets are important in my study, so we sourced stocks from the Centre for Security Research (CRSP) database and equity option from the Option Metrics database. Furthermore, we employed the data mainly related to the level of cash holding from the Compustat database. Furthermore, we obtained insider trading and ownership structure data from the ISSdirector database. In this chapter, we will discuss these four databases and the descriptive statistics of these data.

3.1 Stock and Option Market Liquidity

In this research, stocks are sourced from the Centre for Security Research (CRSP) database in the recent periods from 1996 to 2015, which contains a number of trades and shares outstanding, different types of dividends, low/high/close prices, bid and ask prices, individual return. Also, it provides equal-weighted and value-weighted market returns.

Equity options are selected from the Option Metrics database between 1996 and 2015, which supplies the relatively historical data of price and quality, tools and analytics. Concretely speaking, it not only releases the related company name and industry group, but also provides the option information, such as daily best bid and best ask quotes, Black and Scholes implied volatilities (IV), trading volume, open interest, strike prices, the remaining time to expiration of the option (expressed in years) and option Greeks (e.g., Delta, Gamma, Theta and Vega).

According to previous literature, we perform the following procedure to prepare the stock and equity option data for analysis. We deleted stocks and options related with missing or zero trading volume and price (Cao and Wei, 2010). We deleted missing or zero option open interest and stock share outstanding. We removed abnormal stock and option bid and ask quotes if the bid-ask spread is negative (Sarkar and Schwartz, 2009). To ensure the existence of absolute implied volatility spread, we matched each pair of call and put option of the same underlying stock with the same strike price and maturity and remove non-pair call and put options. Only common stocks (CRSP item SHRCD = 10 or 11) listed on exchanges (Papakroni, 2018). We supplemented equity option data with the daily stock data during the same sample period. The stock identification number, CUSIP is provided by CRSP database which allows the stock data to be merged with equity option data in Option Metrics database. Subsequently, we calculated market liquidity in these two asset markets on a daily basis. Stock liquidity is measured as proportional bid-ask spread and Amihud illiquidity ratio. Option liquidity is measured as volume weighted proportional bid-ask spread and equal weighted absolute implied volatility spread. The formulas of these stock and option liquidity variables are shown in Table 6.1.

Figure 3.1 plots the time series of the monthly stock market liquidity measure, including proportional bid-ask spread and Amihud illiquidity ratio in the Panels A and B, and of the monthly option market illiquidity measure, including volume-weighted proportional bid-ask spread, equal-weighted absolute implied volatility spread, open interest and trading volumes in Panels C and D. Particularly, the most suitable measure of option liquidity in my thesis is relative bid-ask spreads. As argued by Goyenko *et al.* (2015), option volume does not capture illiquidity, or at least information asymmetry part of illiquidity. Furthermore, the bid-ask spread is the most reliable measure of option liquidity.

In Panels A and B, there were downward trends before 2007. Both stock liquidity measures began to rise and reached the peak in 2009, and then decreased considerably from 2009 to 2010. In the last five years, stock liquidity measures were much lower than before, but remained smooth. In Panels C and D, despite certain strikes, option liquidity measures were stable for the whole period. Particularly, they peaked in 2009 and 2015.

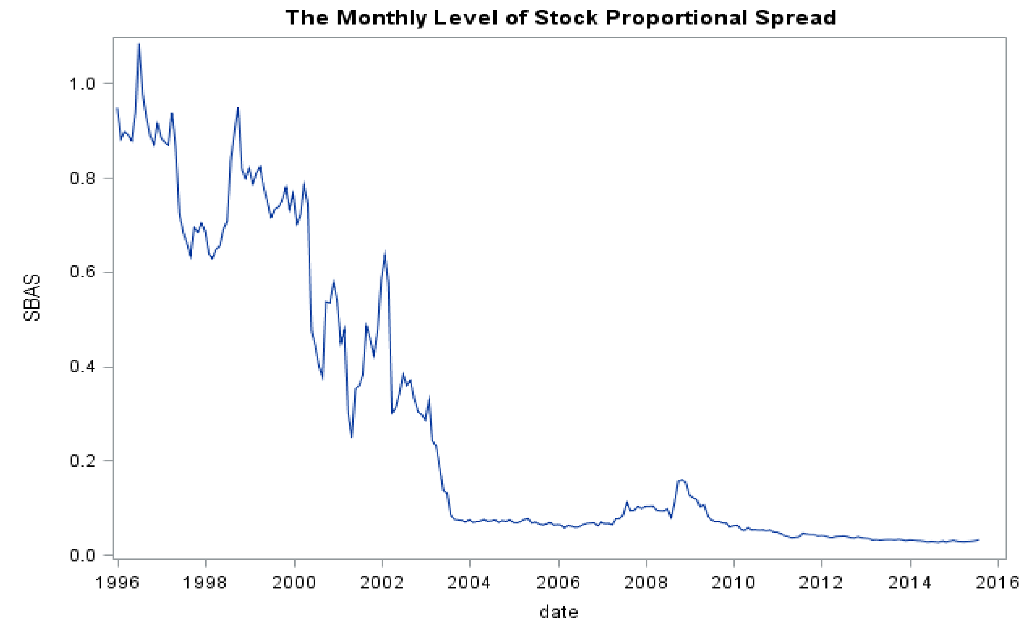
Panel A: Stock Liquidity Measure		
Liquidity	Definition	Formula
Proportional Spread	The daily proportional spread of a stock is measured as the bid–ask spread divided by the midpoint between the bid and ask quotes per day	$SBAS_{i,t} = \frac{SBid_{i,t} - SAsk_{i,t}}{\frac{SBid_{i,t} + SAsk_{i,t}}{2}}$
Amihud Illiquidity Ratio	Amihud illiquidity ratio is the 20-day moving average daily absolute return divided by the trading volume the day before.	$AMIHUD_{i,t} = \frac{\sum_{t=1}^{20} \frac{\lvert R_{i,t} \rvert}{SVol_{i,t}}}{20}$

Panel B: Option Liquidity Measure		
Liquidity	Definition	Formula
Volume Weighted proportional spread	We take the sum of the trading volume times the proportional spread and then takes it divided by the total trading volume per day.	$OBAS_{j,i,t} = \frac{\sum_{i=1}^{n} \frac{OBid_{j,i,t} - OAsk_{j,i,t}}{\frac{OBid_{j,i,t} + OAsk_{j,i,t}}{2}} * OVol_{j,i,t}}{\sum_{i=1}^{n} OVol_{j,i,t}}$
Absolute Implied Volatility Spread	It is the absolute difference between the implied volatilities the same pairs of call and put options on the same underlying stock with the same strike price and the same expiration date We then takes the sum of the absolute implied volatility spread and then takes it divided by the total trading numbers per day	$IVDIFF_{j,i,t} = \frac{\sum_{i}^{n} \lvert IVol_{j,t}^{i,call} - IVol_{j,t}^{i,put} \rvert}{n}$
The Log of Option Open Interest	The natural logarithm of yearly total option open interest.	$OI_{j,i,t} = Log\,(\sum_{i=1}^{n} OI_{j,i,t})$
The Log of Option Trading Volume	The natural logarithm of yearly total option trading volume.	$OVOL_{j,i,t} = Log\,(\sum_{i=1}^{n} OVOL_{j,i,t})$

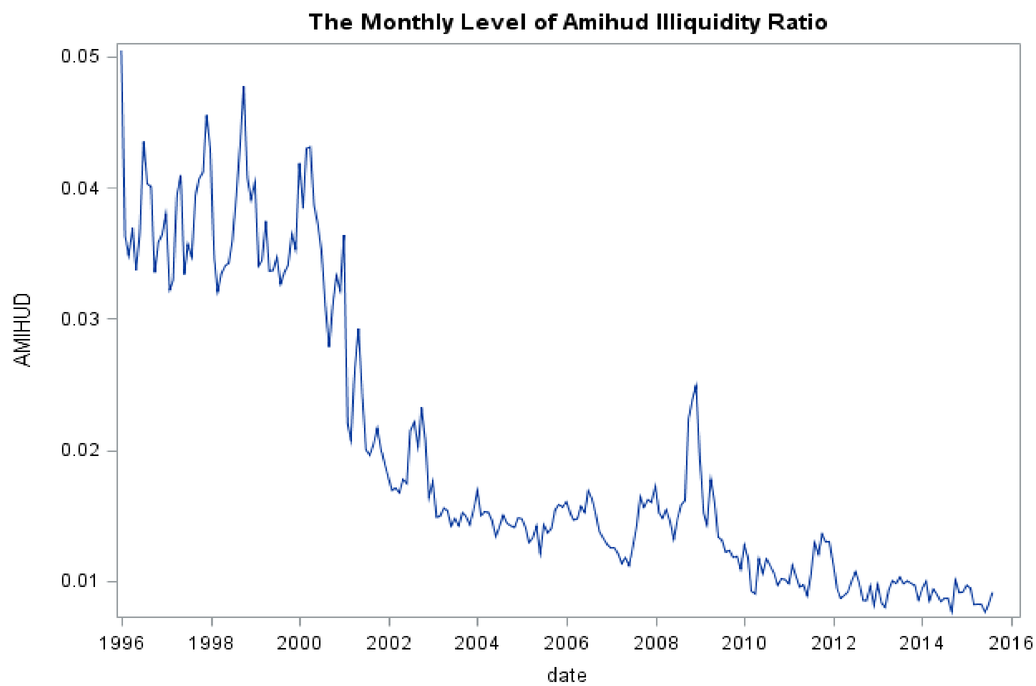
Notes: This table presents formula of stock and option liquidity measures. $R_{i,t}$ is the return on stock i on trading day t. $SBid_{i,t}$ is the bid price on stock i on trading day t. $SAsk_{i,t}$ is the ask price on stock i on trading day t. $OBid_{j,i,t}$ is the bid price of option j written on stock i on trading day t. $OAsk_{j,i,t}$ is the ask price of option j written on stock i on trading day t. $SVol_{i,t}$ is the trading volume on stock i on trading day t. $OI_{j,i,t}$ is the open interest of option j written on stock i on trading day t. $OVol_{j,i,t}$ is the trading volume of option j written on stock i on trading day t. $IVol_{j,t}^{i,call}$ is the implied volatility of call option j written on stock i on trading day t. $IVol_{j,t}^{i,put}$ is the implied volatility of put option j written on stock i on trading day t.

Table 3.1 The Definitions and Formulas of Stock and Equity Option Liquidity Measures

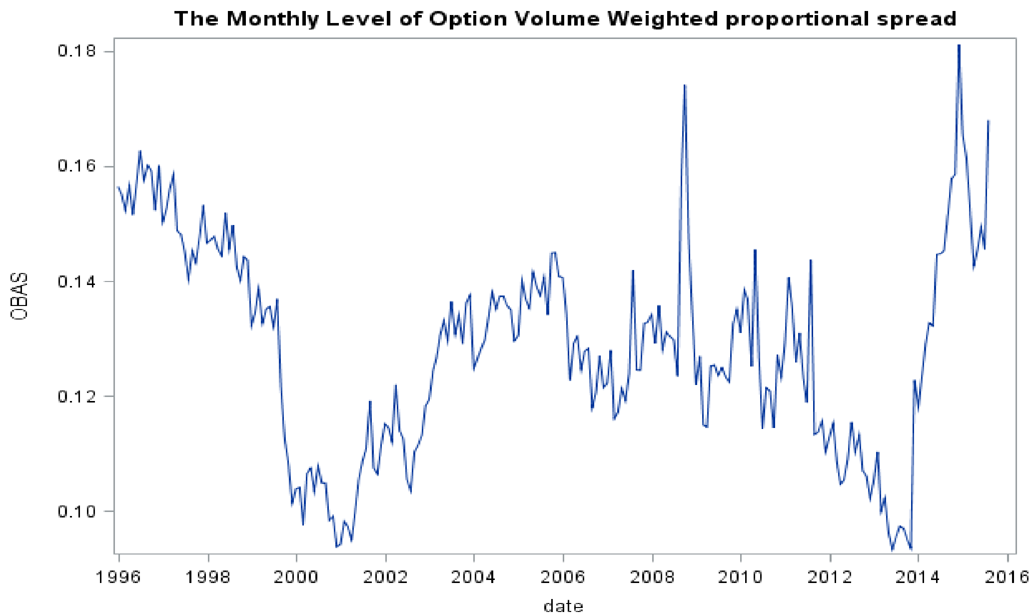
Panel A: The Monthly Level of Stock Proportional Spread



Panel B: The Monthly Level of Amihud Illiquidity Ratio



Panel C: The Monthly Level of Option Volume Weighted Proportional Spread



Panel D: The Monthly Level of Option Absolute Implied Volatility Spread

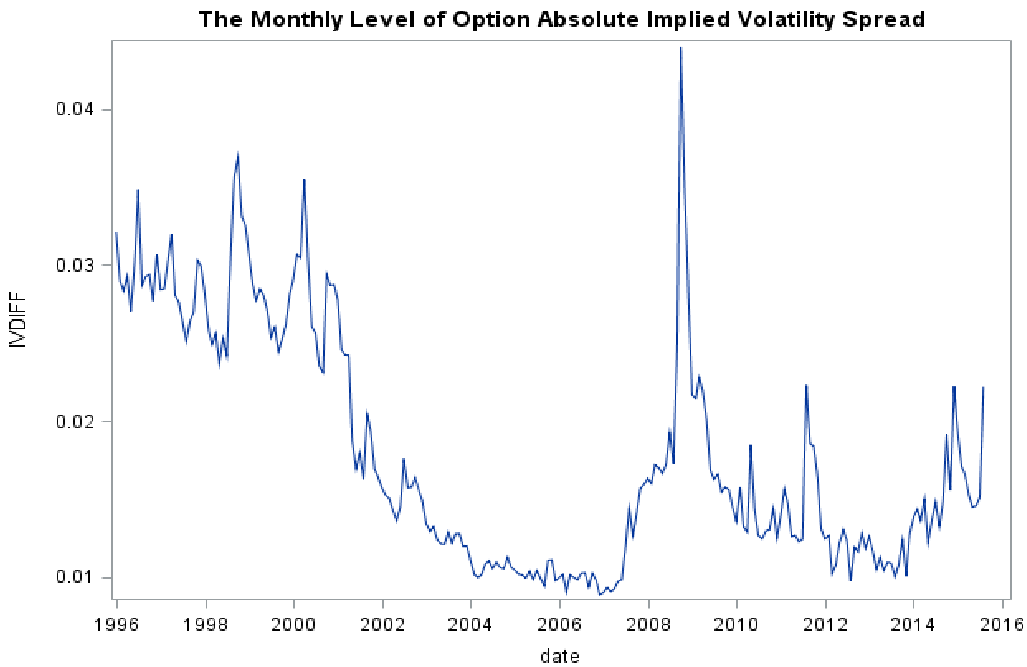
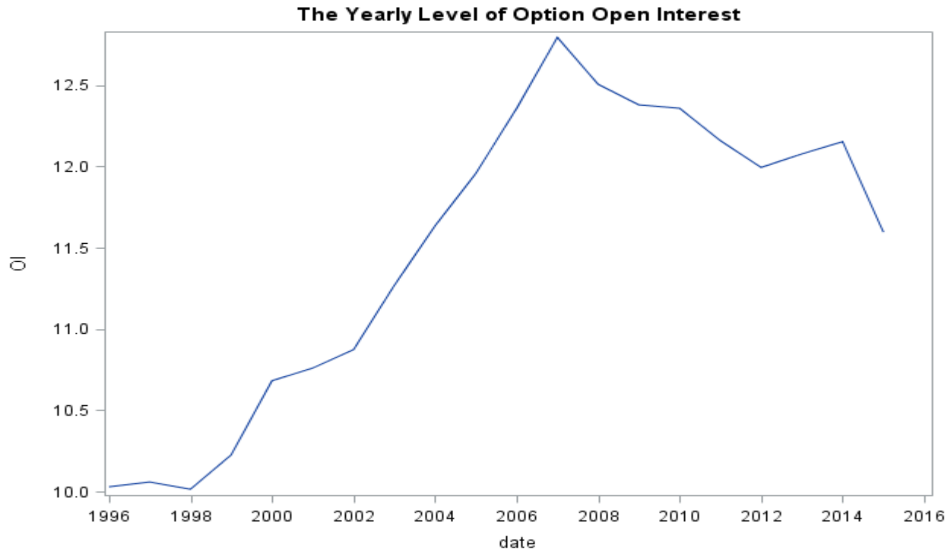


Figure 3.1 The Time Series of Monthly Level of Stock and Option Market Liquidity Measures

Notes: The four panels of Figure 3.1 present the time series of the monthly averaged stock and option market liquidity measures during the whole sample period from January 1996 to August 2015. SBAS is 100 times stock proportional spread. AMIHUD is Amihud illiquidity ratio. OBAS is option volume weighted proportional spread. IVDIFF is equal weighted absolute implied volatility spread.

Panel E: The Yearly Level of Option Open Interest



Panel F: The Yearly Level of Option Trading Volume

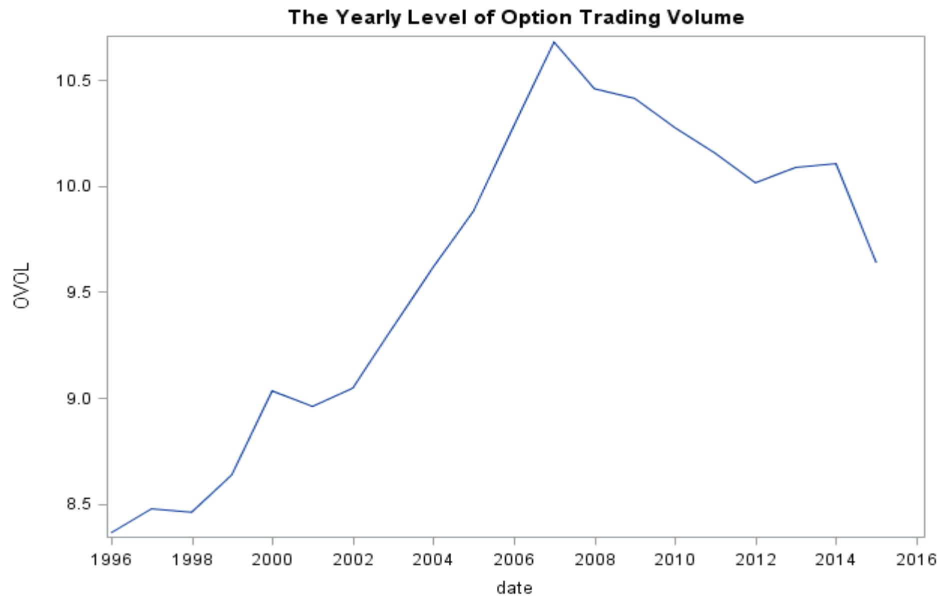


Figure 3.2 The Time Series of Yearly Level of Option Open Interest and Trading Volume

Notes: The two panels of Figure 3.2 present the time series of the natural logarithm of yearly l option trading volume and open interest during the whole sample period from January 1996 to August 2015. OI is the natural logarithm of option open interest. OVL is the natural logarithm of option trading volume.

Figure 3.2 plots the time series of the total yearly option open interests and trading volumes in the Panels E and F. There were gradually growing trends before 2007 and then decreased after 2007. As only eight months were recorded in 2015, option open interests and trading volumes were at the bottom in 2015.

Table 3.2 presents the descriptive statistics for stock and equity option market liquidity in the sample period between 1996 and 2015. Panel A shows the firm-level market liquidity measures in stocks and options on a daily basis. The average of all stock proportional bid-ask spread is 0.30, and the standard deviation is 0.66. In particular, the maximum value is massively large, up to 196.04. The average of Amihud illiquidity ratio is 0.04, which is similar to the median value (0.02). The average option proportional bid-ask spread is 0.16. The standard deviation is 0.12. The average of option equal-weighted implied volatility spread is 0.03, slightly higher than the median value (0.02). In short, except stock proportional bid-ask spread, the other three liquidity measures are not considerably volatile. Panel B shows that firm-level option open interest and trading volume on a yearly basis. The average values of option open interest and trading volume are slightly lower than their median values. Panel C shows the firm-level averaged stock and option liquidity measures in the same period. The average of all stock proportional bid-ask spread is 0.21, and the standard deviation is 0.34. The presence of huge maximum value (4.79) causes the median value (0.10) to be much lower than average. Among the other three spread measures, their averaged and median values are similar and even the same. The averaged and median values of option open interest are around 11.6. The averaged and median values of option trading volumes are 9.7. Panel D shows the market-level averaged stock and option liquidity measures. The patterns of these four spread measures are similar to those of Panel C. The patterns of option open interest and trading volume are similar to those of Panel B.

Table 3.3 reports the Pearson correlations among stock and option liquidity measures. Panel A shows the firm-level market liquidity measures in stocks and options on a daily basis. Panels B and C show the firm-level averaged and market-level averaged stock and option liquidity measures in the same period, respectively. In these three panels, all correlations coefficients between stock and option liquidity measures are significantly positive. Except for low correlations coefficients between stock and option proportional spread (0.04) in panels A and B, others are more highly significant, higher than 0.15. This finding indicates that stock and option liquidity measures have close relationships. ‘The positive correlation is consistent with the derivative-hedge theory proposed by Cho and Engle (1999)’ (Li, 2016).

Panel A: Daily Firm-Level Stock and Equity Option Liquidity						
	No.Firm	Mean	Median	StdDev	Max	Min
SBAS	2302	0.30	0.08	0.66	196.04	0
AMIHUD		0.04	0.02	0.08	10.06	0
OBAS		0.16	0.13	0.12	1.89	0.003
IVDIFF		0.03	0.02	0.05	3.76	0
Panel B: Yearly Firm-Level Equity Option Open Interest and Trading Volume						
	No.Firm	Mean	Median	StdDev	Max	Min
OI	2302	11.61	11.67	3.34	21.76	0.69
OVOL		9.69	9.73	2.90	18.72	0.69
Panel C: Firm-level Averaged Stock and Equity Option Liquidity						
	No.Firm	Mean	Median	StdDev	Max	Min
SBAS	2302	0.21	0.10	0.34	4.79	0.01
AMIHUD		0.05	0.03	0.06	0.62	0
OBAS		0.17	0.16	0.06	0.47	0.04
IVDIFF		0.02	0.02	0.02	0.22	0.01
OI		11.43	11.23	2.54	19.35	5.51
OVOL		9.53	9.36	2.19	16.31	4.41
Panel D: Market-level Averaged Stock and Equity Option Liquidity						
	No.Firm	Mean	Median	StdDev	Max	Min
SBAS	2302	0.28	0.08	0.31	1.30	0.02
AMIHUD		0.02	0.02	0.01	0.06	0.01
OBAS		0.13	0.13	0.02	0.29	0.07
IVDIFF		0.02	0.02	0.01	0.10	0.01
OI		11.49	11.80	0.93	12.79	10.01
OVOL		9.60	9.76	0.75	10.68	8.36

Notes: This table shows descriptive Statistics of market liquidity in stocks and options during 1996 and 2015. SBAS is 100 times stock proportional spread. AMIHUD is Amihud illiquidity ratio. OBAS is option volume weighted proportional spread. IVDIFF is equal weighted absolute implied volatility spread. OI is the natural logarithm of option open interest. OVL is the natural logarithm of option trading volume. This table contains the number of firms, and the mean, median, standard deviation, maximum and minimum.

Table 3.2 Descriptive Statistics of Stock and Equity Option Liquidity

Panel A: Pearson Correlation between Daily Firm-Level Stock and Option Liquidity				
	SBAS	AMIHUD	OBAS	IVDIFF
SBAS	1			
AMIHUD	0.24 ***	1		
OBAS	0.04 ***	0.16 ***	1	
IVDIFF	0.16 ***	0.20 ***	0.25 ***	1
Panel B: Pearson Correlation between Firm-Level Averaged Stock and Option Liquidity				
	SBAS	AMIHUD	OBAS	IVDIFF
SBAS	1			
AMIHUD	0.40 ***	1		
OBAS	0.04 **	0.34 ***	1	
IVDIFF	0.37 ***	0.41 ***	0.27 ***	1
Panel B: Pearson Correlation between Market-Level Averaged Stock and Option Liquidity				
	SBAS	AMIHUD	OBAS	IVDIFF
SBAS	1			
AMIHUD	0.92 ***	1		
OBAS	0.19 ***	0.17 ***	1	
IVDIFF	0.76 ***	0.77 ***	0.36 ***	1

Notes: Tshi table presents Pearson correlation coefficients between stock and option liquidity measures. SBAS is stock proportional spread. AMIHUD is Amihud illiquidity ratio. OBAS is option volume weighted proportional spread. IVDIFF is equal weighted absolute implied volatility spread All the p-values are shown like *** Significance at 1% level. The sample period spans from 1996 to 2015.

Table 3.3 Pearson Correlation between Stock and Equity Option Liquidity

3.2 Firm-Specific Stock Price Crash Risk

Stock market crash risk is defined as the significant and sudden stock price decreases in the absence of large public and material fundamental news. Due to this rare occurrence of this declining tendency for stock prices, investors suffer heavy losses (Liu and Zhong, 2018). Negative information hoarding theory is the most widely recognized argument used to explain the formation mechanisms of crash risk (Bhatia *et al*., 2014). It argues that the accumulated bad information triggers crash risk. Specifically, some disadvantages and potential influences on compensation contracts, career concerns, and empire building will create an incentive for firms to curb bad news from markets for an extended period. The accumulation of bad news tends to maintain or accelerate price inflation, which continually fuels the bubble. Beyond the tipping point, this unfavourable information will flow to the market at once, and consequently bringing about substantial stock price declines (Chang *et al*., 2017).

Based on Jin and Myers (2006) and Chang *et al*. (2017), stock price crash risk is measured as a remote and negative outlier in the residual stock return for each firm. Three proxies of crash risk are the negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH), respectively. Our study focuses on publicly listed U.S. industrial firms and removes utility stocks (that is, companies with the Standard Industrial Classification (SIC) falling between 4900 and 4999). The definitions and formulas of these proxies are shown in Table 3.4.

Variable	Definition and Formula
Firm-Specific Daily Returns	This paper estimates firm-specific daily returns from an expanded market and industry index model regression for each firm and year (Hutton *et al*., 2009). $r_{j,t} = \alpha_i + \beta_{1,j} * r_{m,t-1} + \beta_{2,j} * r_{i,t-1} + \beta_{3,j} * r_{m,t} + \beta_{4,j} * r_{i,t} + \beta_{5,j} * r_{m,t+1} + \beta_{6,j} * r_{i,t+1} + \varepsilon_{j,t};$ where $r_{j,t}$ is the return on stock j in day t, $r_{m,t}$ is the return on the CRSP value weighted market index in day t, and $r_{i,t}$ is the return on the Fama-French value-weighted 48 industry index. The firm-specific daily return is the natural log of one plus the residual return from the regression model.
NCSKEW	NCSKEW is the negative coefficient of skewness of firm-specific daily returns. It is the negative of the third moment of each stock's firm-specific daily returns, divided by the cubed standard deviation.
	Negative coefficient of skewness of firm-specific daily returns (NCSKEW) is $$NCSKEW_{j,t} = \frac{-(n*(n-1)^{\frac{3}{2}} * \sum R_{j,t}^3)}{(n-1)*(n-2)*(\sum R_{j,t}^2)^{\frac{3}{2}}}$$ where n is the number of observations of firm-specific daily returns in year T.
DUVOL	DUVOL is the log of the ratio of the standard deviation of firm-specific daily returns for the ''down-day" sample to standard deviation of firm-specific daily returns for the ''up-day" sample over the fiscal year. For any stock j over a one-year period, this paper separates all the days with firm-specific daily returns above (below) the mean of the period and call this the 'up' ('down') sample.
	The down-to-up volatility of firm-specific daily returns (DUVOL) is $$DUVOL_{j,t} = log\,\{\frac{[(n_u-1)*\sum_{DOWN} R_{j,t}^2]}{[(n_d-1)*\sum_{UP} R_{j,t}^2]}\}$$ where n_u (n_d) are the number of up (down) days in year t, respectively.
CRASH	The crash dummy (CRASH) is defined as a dummy variable equal to 1 if there are one or more weekly returns falling 3.09 standard deviations below the mean daily returns over the fiscal year, and 0 otherwise.

Table 3.4 The Definitions and Formulas of Stock Price Crash Risk

Table 3.5 displays the descriptive statistics of stock price crash risk measures across 2185 firms from 1996 to 2015. Panel A shows the yearly firm-specific crash measures. The average of negative skewness (NCSKEW) is 0.60, and the standard deviation 2.60. It ranges from -12.30 to 15.65. The averages of the down-to-up volatility (DUVOL) are 0.14, much larger than the median value (-0.02). Crash dummy (CRASH) is 0.65, indicating that over half of firms are subjected to crash risk. Panel B shows the firm-level averaged crash measures in the same period. Except for negative skewness (NCSKEW), the averaged values of the down-to-up volatility (DUVOL) and crash dummy (CRASH) are close to their median values. All the averaged and median values are positive, which imply that there are more 'crash-prone' stocks (Chang *et al*., 2017).

Panel A: Yearly Firm-Level Stock Price Crash Risk						
	No.Firm	Mean	Median	StdDev	Max	Min
NCSKEW		0.60	0.08	2.60	15.65	-12.30
DUVOL	2185	0.14	-0.02	1.24	8.08	-5.36
CRASH		0.65	1	0.48	1	0
Panel B: Firm-level Averaged Stock Price Crash Risk						
	No.Firm	Mean	Median	StdDev	Max	Min
NCSKEW		0.50	0.41	0.83	5.93	-3.69
DUVOL	2185	0.12	0.12	0.49	2.99	-3.32
CRASH		0.59	0.63	0.24	1	0

Notes: This table shows descriptive Statistics of stock price crash risk measures, such as Negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH) during 1996 and 2015. This table contains the number of firms, and the mean, median, standard deviation, maximum and minimum.

Table 3.5 Descriptive Statistics of Stock Price Crash Risk

Table 3.6 reports the Pearson correlations among stock price crash risk measures. Panel A shows the yearly firm-level crash measures. Panels B shows the firm-level averaged crash measures in the same period. In these panels, all correlations coefficients are significantly positive (lager than 0.38). These results indicate that there three crash measures are closely related.

Panel A: Pearson Correlation between Yearly Firm-Level Stock Price Crash Risk			
	NCSKEW	DUVOL	CRASH
NCSKEW	1		
DUVOL	0.90 ***	1	
CRASH	0.38 ***	0.46 ***	1

Panel B: Pearson Correlation between Firm-level Averaged Stock Price Crash Risk			
	NCSKEW	DUVOL	CRASH
NCSKEW	1		
DUVOL	0.85 ***	1	
CRASH	0.47 ***	0.42 ***	1

Notes: This table presents Pearson correlation coefficients between stock price crash risk measures, such as Negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH). All the p-values are shown like *** Significance at 1% level. The sample period spans from 1996 to 2015.

Table 3.6 Pearson Correlation between Stock Price Crash Risk

3.3 Excess Cash

To calculate excess cash, we use the Compustat database provided by Capital IQ from 1997 to 2015. It includes the fundamental and market information on publicly held firms. More specifically, it contains annual and quarterly income statement, balance sheet, cash flow statement and the items of supplemental data in firms. Using the stock identification number, we extract details related to the level of cash holding, net asset values, research and development expenses, and capital expenditures for the firms in our samples.

Based on Asem and Alam (2014), we focus on publicly listed U.S. industrial firms and exclude utilities and financial stocks (that is, companies with the Standard Industrial Classification (SIC) falling between 4900 and 4999, and between 6000 and 6999). We also exclude firms with negative assets, negative sales, and those with annual assets or sales growth larger than 100% to reduce the outlier effects (Huang and Mazouz, 2018). Based on the above criteria, we analyse a sample of 908 firms over the sample period.

Following Huang and Mazouz (2018), the residual of a cross-sectional regression of cash holdings on firm characteristics:

$$Cash_i = \alpha_0 + \alpha_1 CF_i + \alpha_2 LEVERAGE_i + \alpha_3 MTB_i + \alpha_4 Size_i + \alpha_5 NWC_i + \alpha_6 CAPEX_i + \alpha_7 DIV_i + \alpha_8 R\&D_i + \alpha_9 INDSIG_i + \varepsilon_i; \quad (1)$$

The dependent variable $Cash_i$ is the natural log of cash and short-term investments (*che*) scaled by net assets (*at-che*). The independent variables are as following: CF_i is the ratio of cash flows (*ebitda-xint-txt-dvc*) scaled by net assets; $LEVERAGE_i$ is the ratio of total debt (*dltt + dlc*) scaled by net assets; $MTB_i$is the market value of assets divided by total assets (*at-ceq +(csho* $*$ *prcc_f)/ at*); $Size_i$is the natural log of net assets (*at-che*) deflated in 1994 dollars; NWC_i is net working capital (*wcap-che*), scaled by net assets; $CAPEX_i$ is capital expenditures (*capx*) scaled by net assets; DIV_i is a dummy variable with a value of one if a firm pays dividends (*dvc*) and zero, otherwise; $R\&D_i$is research and development expenses scaled by sales (*RD_sale*); industry cash flow risk $INDSIG_i$, defined as the mean of the ratio of the standard deviations of cash flows dividend by the total assets over 20 years for firms in the same

.

To mitigate outlier effects, we apply the winsorizing method to remove the extreme variables at the 1st and 99th percentiles each year. The exponential form of residual is calculated as firm i's excess cash *ECASH* each year. A positive (negative) residual shows that cash holding in each firm is greater (less) than the need for its normal operating and investing activities in that year.

Table 3.7 presents the descriptive statistics of the firm characteristics computed across 1171 firms over the whole sample period. All these measures of firm characteristics have non-negative averaged and median values. The average ratio of cash holding to the net asset is 0.41, and the standard deviation of the ratio is 0.18. The average of excess cash is 0, but the median value is positive (0.14). It ranges from -5.46 to 4.56.

Variable	No. Firms	Mean	Median	StdDev	Max	Min
CASH		0.41	0.18	0.68	14.55	0.001
ECASH		0	0.14	1.10	4.56	-5.46
CF		0.07	0.10	0.28	0.78	-5.30
LEVER		0.25	0.20	0.30	4.82	0
MTB		0.31	0.07	0.75	10.57	0
SIZE	1171	7.06	7.11	1.72	11.88	1.43
NWC		0.07	0.08	0.20	0.59	-1.80
CAPEX		0.06	0.05	0.05	0.42	0.002
RND		0.17	0.04	0.82	41.64	0
DIV		0.40	0	0.49	1	0
INDSIG		0.07	0.07	0.03	0.14	0.02

Notes: This table shows the descriptive statistics of firm characteristics from 1997 to 2015. CASH includes cash and short-term investments scaled by net assets; ECASH is the residual obtained from the regression equation (1); CF is earnings after interest, dividends, and taxes, but before depreciation scaled by net assets; MTB is the ratio of market value of assets to total assets on a basis point; SIZE is the natural logarithm of net assets; LEVER is the ratio of total debt to net assets; DIV is a dummy variable with a value of one if the firm pays dividends, and zero otherwise; CAPEX is 100 times the ratio of capital expenditures to net assets; RND is the ratio of research and development expenditures to sales; NWC is the net working capital (net of cash), scaled by net assets; INDSIG is industry cash flow risk, defined as the mean of the ratio of the standard deviations of cash flows to the total assets over 20 years for firms in the same industry (by 2-digit Standard Industrial Classification code).

Table 3.7 Descriptive Statistics of Excess Cash Holdings and Determinants

Table 3.8 shows the average coefficients and the *t*-statistics (in parentheses) of the regression (equation 1) used to capture excess cash holding. Similar to the results displayed in Asem and Alam (2014), we observe that earnings (*CF*), the research and development expenditures (*RND*), and industry cash flow risk (*INDSIG*) could explain the ratio of cash holding to net assets. Therefore, firms with higher profitability, more research and development activities, or larger exposure to industrial cash flow fluctuations, tend to retain more cash. Furthermore, firm size, leverage ratio and the level of working capital also affect the degree of cash holding. Larger size companies or those that have greater leverage and larger working capital are prone to hold less cash reserves. These effects are significant at one percent level. The R-square obtained from the regressions averages 42 percent, a value higher than one obtained in Asem and Alam (2014).

	Dependent variable: Cash
CF	0.63 (2.52) **
LEVER	-0.56 (-2.11) **
MTB	0.50 (4.16) ***
SIZE	-0.46 (-9.91) ***
NWC	-1.27 (-4.76) ***
CAPEX	0.82 (0.71)
RND	0.60 (3.3) ***
DIV	-0.35 (-2.6) ***
INDSIG	7.08 (3.91) ***
CONSTANT	0.85 (2.54) **
RSQ	0.42

Note: This table shows the mean coefficients and the mean *t*-statistics (in parentheses) of the regressions (1) estimated over the sample period 1997 to 2015. The dependent variable, CASH, is the natural log of cash and short-term investments scaled by net assets; CF is earnings after interest, dividends, and taxes, but before depreciation scaled by net assets; LEVER is the ratio of total debt to net assets; MTB is the market value of assets divided by total assets; SIZE is the natural log of net assets deflated in 1994 dollars; NWC is the net working capital (net of cash), scaled by net assets; CAPEX is capital expenditures scaled by net assets; DIV is a dummy variable which equals one if the firm pays dividends and zero otherwise; RND is the research and development expenditures scaled by sales; INDSIG is industry cash flow risk, defined as the mean of the ratio of the standard deviations of cash flows to the total assets over 20 years for firms in the same industry (by 2-digit Standard Industrial Classification code). We use the previous year details of the control variables CF, LEVER, MTB, SIZE, NWC, CAPEX, DIV, RND, and INDSIG in the regressions. We perform the regression model (1) each year over the sample period and obtain the level of excess cash for each firm on an annual basis. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 3.8 Measuring Excess Cash Holdings

3.4 Insider Trading and Board Structure

Corporate governance with different aspects of managerial ownership and the board structure of firms plays an important role in investment decisions (Ozkan and Ozkan, 2004). Following previous empirical papers (See, Ozkan and Ozkan, 2004; Harford *et al.,* 2008; Chung *et al.,* 2010; Alam *et al.,* 2019), the degree of insider trading is defined as:

$$Insider_{i,t} = \frac{InsiderShare_{i,t}}{TotalShare_{i,t}}, \qquad (2)$$

where $InsiderShare_{i,t}$ is the total number of shares traded by insiders (namely, executive directors), $TotalShare_{i,t}$ is the total number of shares outstanding for firm i at time t.

Based on Ozkan and Ozkan (2004), we use NONEX, the natural logarithm ratio of non-executive directors to the total number of board directors to capture the board independence. A higher ratio indicates the firms with greater outside (non-executive) director representation and more board independence while a lower ratio indicates the firms dominated by inside (executive) directors.

Institutional Sharehold Services (ISS) database provides corporate governance information about the board, compensation, shareholder proposals, the records of institutional voting and the results of shareholder meeting. We obtain insider trading and the degree of board independence details from the ISS Director data [15] over the period between Jan 1, 2007 to Aug 31, 2015.

Table 3.9 displays the descriptive statistics of corporate governance measures from 2007 to 2015. Panel A shows the yearly firm-level governance measures. The average of insider ownership is 0.17 and the standard deviation 0.44. It ranges from 0 to 11.24. The average of the board independence is 0.80, slightly less than the median value (0.82). Panel B shows the firm-level averaged governance measures in the same period. The average of insider ownership (0.18) is much larger than the median value (0.05) while the average of board independence (0.79) is close to median value (0.82). In panel C, the mean and median values of insider ownership and board independence are similar at the market level.

[15] Details of the ISS Director data could be found via the URL link (www.issgovernance.com/esg/director-data/).

Panel A: Yearly Firm-Level Corporate Governance						
Variable	No. Firms	Mean	Median	StdDev	Max	Min
INSIDER	1337	0.17	0.04	0.44	11.24	0
NONEX	2302	0.80	0.82	0.11	1	0

Panel B: Firm-Level Averaged Corporate Governance						
Variable	No. Firms	Mean	Median	StdDev	Max	Min
INSIDER	1337	0.18	0.05	0.42	5.94	0
NONEX	2302	0.79	0.82	0.10	0.94	0

Panel C: Market-level Averaged Corporate Governance						
Variable	No. Firms	Mean	Median	StdDev	Max	Min
INSIDER	1337	0.17	0.18	0.03	0.20	0.13
NONEX	2302	0.80	0.80	0.01	0.81	0.78

Notes: This table shows the descriptive statistics of corporate governance measures from 2007 to 2015. NONEX is the ratio of the number of independent director and total board directors. As share outstanding is scaled by 1,000 in CRSP database, INSIDER is one thousand multiplied by the ratio of the total number of shares traded by insiders (namely, executive directors) to the total number of shares outstanding.

Table 3.9 Descriptive Statistics of Corporate Governance

Chapter 4. Literature Review of Excess Cash and Market Liquidity

This chapter is divided into five parts. The first part explains the reasons why firms hold cash reserves. The second part introduces the different motives for holding cash, such as transactions motive, precautionary motive, speculative motive, agency motive and other motives (Jensen and Meckling, 1976; Jensen, 1986; Myers and Majluf, 1984). These motives laid down the foundations of the theories used to illustrate the association between firm characteristics and corporate cash holdings (Opler *et al.*, 1999). The third part mainly discusses these theories, such as the trade-off theory, pecking order theory and agency theory. Based on these theoretical arguments, the fourth part points out the financial determinants of cash holdings (Opler *et al.*,1999; Harford *et al.*, 2008). Regarding the current studies, they focused on whether investors sanction firms with excess cash (Simutin, 2010; Asem and Alam, 2014). According to different investors' concerns and perspectives, the last part investigates the role of excess cash in asset market liquidity.

4.1 The Reasons for Using Cash Holdings

Cash holdings refer to cash assets held by a firm in contrast to other assets, such as real estate, stocks, and bonds. In traditional financial theory, 'cash and cash equivalents are the most liquid asset on a firm's balance sheet. A firm needs to hold cash and cash equivalents to carry out its daily operations (Mihai and Radu, 2015). In a perfect market with the absence of transaction costs or financing obstacles, firms are not required to hold additional cash in their account as there are no costs to and raise financial resources from the external market. In other words, cash holding is irrelevant in this market. In practice, the findings of the literature on whether the firms should hold excess cash are inconclusive and can be divided into two opposing directions.

In certain situations, holding excess cash is regarded as an action that compromises the company interests. Several studies explained that the opportunity costs associated with cash holdings cannot be undervalued, and they opposed the firms holding excessive cash in their account (Han and Qiu, 2007). For instance, the interest rates provided by the majority of commercial banks have achieved the lowest historical record. If the firms invest in other tangible and intangible assets wisely and strategically, they will probably acquire the financial return, which might higher than that just deposit into the bank accounts. What is more, the high inflation rate will compromise or even diminish the spending power of the firms in the future if the saving accounts only offer the businesses' low interest rate. When the time value takes account, the inflation rate will more likely outgrow the low-yield investments and eventually, the businesses lose their purchasing power. In short, the more cash the firms keep, the higher the inflation risk they expose.

In addition, the dividend payout can signify to the investors that firms have healthy financial conditions. The sharing of excess cash among shareholders implies the business has sufficient financial resources to buffer the adverse effect caused by economic downturns or crashes. Furthermore, the active dividend payout stocks are usually less volatile and attach to the stable equity prices. Following the Bates *et al*. (2009) argument, firms can improve their ability to access the financial resource from the capital markets by initiating the dividend payment policy, thereby this will incentive the firms to hold less cash. Their payout can provide confidence to the investors because businesses are exposed to a low level of liquidity risk, and investors can acquire attractive returns periodically. Regarding the dividend payout perspective, firms holding less cash can gain benefits by increasing capital assessment from the market and obtaining confidence from investors.

Despite the opportunity costs and dividend payout aspects, some scholars also showed that the advancement of financial technology further reduces the firms to keep extra cash (Bates *et al*., 2009). For instance, firms can use these technologies to keep tracking their liquidity levels precisely and forecast the cash they required either to maintain the normal operations or to respond to the urgent need. Further, businesses acquired with expanded financial knowledge become more efficient to do the transaction, so the transaction-based requirements for cash holdings can be reduced. More than that, the variety of financial derivatives available in the markets help businesses to hedge unexpected circumstances effectively and economically, thereby reducing the precautionary demand for cash.

While the risk management theory indicates that firms are necessary to hold liquid assets to mitigate idiosyncratic and systematic risks, Irvine and Pontiff (2009) found that the higher the idiosyncratic risks, the more volatile of firm's cash flows. This situation is particularly vulnerable to the newly listed firms as they have permanently higher idiosyncratic risks, and the boards are aware of whether their firms are financially constrained or not (Kapadia, 2006; Bates *et al*., 2009). To respond to the potential increased cash flow risk, these firms have the precautionary motive by reserving extra cash to avoid financial distress. Unlike idiosyncratic risk, the systematic risk is unhedgeable, and the firms require to reserve extra cash for financial risk management. Because of lacking liquidity, the businesses are hard to survive in the recession period. The proponents of the excessive cash holding strategy also point out that firms need to raise capital with transaction costs. Thereby they might expose the underinvestment risk in an imperfect market. By studying the actual situations, Keynes (1936) pointed out two main advantages of cash holdings. In one aspect, the firm does not need to liquidate the assets when payments are due, thereby reducing the transaction costs. Furthermore, cash holding can provide the essential buffer to the firms and protect them from financial distress due to unforeseen contingencies. Based on the extant literature, several other reasons explain why the firms incentivize to hold excess cash (Mihai and Radu, 2015). For example, the firms can pay all the operating activities in due time and avoid any delay penalties. The extra cash holding also serves the business to prepare for the unexpected circumstance. On the one hand, the surplus cash can be spent on trade discounts and profitable investments, which are favourable to the firm's growth. On the other hand, the excess cash holding can be either used in emergency conditions or assess the financing facilities granted by the banks.

In short, the surplus of cash is less likely to have a negative impact on the firm's operation and relieve several financial problems when comparing with a cash shortage. Under cash shortage circumstances, the firms will experience financial distress such as the breach of short-term obligations and the increasing cost of capital required by the external investors (Mihai and Radu, 2015). Overall, firms are favourable to reserve extra cash to keep their business as usual regarding the financial considerations.

4.2 Motives for Holding Cash

The extant academic literature discussed the motives comprehensively behind the firms to hold excess cash in their saving accounts. For instance, Keynes (1936) indicated that the cash holding phenomenon is stimulated by the transactions motive, the precautionary motive and speculative motive. First, most of the normal business activities are closed by cash payment. In case that the firms are lack of cash, they may need to liquidate their financial assets, such as real properties and machines, to keep operating and observing their contractual obligations. Yet, these strategies will incur substantial transaction costs, especially for smaller firms. The cash holding can minimize these costs and avoids the firms selling their assets at an undervalued price. Secondly, the environments of the business world are always full of uncertainties, and the economic downturn will stress the business financial conditions. To meet these unexpected contingencies, the cash holding can act as a precautionary measure and provide invaluable liquidity to the firms surviving in a hard time. More importantly, this effect is more pronounced to financially constrained firms. Thirdly, in a similar vein as the precautionary motive, the excess cash reserve can be deployed by firms to invest in the value-adding projects that suddenly appear in the market, such as takeover activities. Instead of seeking assistance from external funds, the cost of capital of these speculations will become lower by using the existing cash holding. It is noteworthy that the financial firms are more eager to hold cash due to the speculative motive (Mihai *et al*., 2018). Comparing with non-financial firms, the characteristics and specialization of financial counterparts have a higher incentive to establish the cash reserve and profit from such unexpected investment opportunities (Van Horne and Wachowicz 2005). In this paper, we will focus on the non-financial corporations and the speculative motive will be less discussed.

Furthermore, findings of some studies attributed the firm to hold excess cash are due to tax and agency motives (Bates *et al*., 2009; Hendrawaty, 2019; Chen *et al*., 2020). Regarding the tax motive, multinational corporations are paid extra attention in this aspect as they generate a large amount of earnings abroad. Proposed by Foley *et al*. (2007), international companies usually prefer to hold excess cash in countries with low tax rates. This strategy also helps them avoid corporate taxes charged on the repatriation of foreign money. From the legal perspective, the foreign profits earned from affiliations abroad are only taxed by the local government where they operate and earn. Because of the high repatriation tax consequences, it is favourable to the multinational firms, particularly the financially unconstrained firms and global technology giant, to reserve cash in the local account with the lower tax rate (Foley *et al*., 2007). Nevertheless, local firms that have no such comparative tax advantages will bear substantial financial losses by withholding extra cash due to the tax charged on interest income. Hence, domestic firms usually employ the credit line or debt capacity rather than saving cash to maintain their liquidity. Also, this debt can deduct the interest payments paid to the government and thereby, the domestic firms can preserve their revenue. In short, the local firms have a lower tendency to hold cash than the international firms because of the tax motive. In this paper, we do not divide firms into multinational and domestic level and this tax motive will be less discussed.

4.2.1 Transaction Motive

As mentioned previously, the transaction cost is one of the motives accounting firms need to hold excess cash. This problem emerges when the firms convert their tangible or intangible assets to cash in response to unpredictable events. Mulligan (1997) argued a further step that the economic scale in transaction motive decreases with the firm size as large businesses have more measures and resources to tackle the cash shortage problem. These similar results can be found in several studies, such as Baumol (1952), Meltzer (1963), Miller and Orr (1966) and Hendrawaty (2019). Furthermore, the asymmetry between the short-term cash inflows and outflows within the firms suggests that reserving cash to maintain normal and daily operations is essential to the businesses (Baum *et al*., 2004). If the businesses do not have enough cash to oblige their contractual payments, they will have the chance of bankruptcy. Therefore, firms are forced to prepare sufficient operational cash holdings to avoid this adverse consequence and the size of this holding can be estimated by modelling the future firms' cash inflows and outflows (Mahai and Radu, 2015).

In addition, Han and Qiu (2007) indicated that firms need to hold a certain amount of cash to pay for extra investment expenditure due to the presence of asymmetric information in the market. According to the traditional finance model, the cost of external funding is normally higher than internal reserved capitals (Myers and Majluf, 1984). Also, the brokerage cost cannot be neglected when firms raise the necessary money from the capital market for a short period (Miller and Orr, 1966). No doubt that the rush sales of assets to meet the unexpected circumstances will only generate cash that is lower than their intrinsic or true value (Chua, 2012). By minimizing these transaction costs, it is important for the firms to reserve cash.

4.2.2 Precautionary Motive

Regarding the precautionary purpose, this is the prominent reason behind the companies having cash holdings. Today, most people recognize that the world is full of uncertainties. This emotion becomes stronger, particularly after the outbreak of the Covid-19 pandemic in which the economic and political landscape around the globe will change completely. The lectures from the financial crisis in 2008 and Covid-19 teach firms that accessing external finance is costly when the confidence in the market is low. In order to survive in these unpredictable events, firms need to have extra cash holdings to operate as usual to reduce the opportunity from resorting to the capital market (Kinnunen, 2015). This opinion is also shared by Gao *et al*. (2013), who indicated unstable economic conditions force the companies to reserve extra cash to prepare for the potential adverse shock. Furthermore, Faulkender and Wang (2006) proposed that firms are conducive to holding cash during a great financial strain period as the opportunity cost of liquidity is low. More importantly, financially constrained firms are more cautious and demand larger cash holding than their counterparts (Almeida *et al*., 2004). The strategic cash holding by the firms is important to combat the severe economic downturns as the capital markets are almost inaccessible, and the cash becomes the scarce commodity (Pinkowitz *et al*., 2006). In this context, the cash holdings by business organizations seem to preserve their assets' value or take advantages of future financial opportunities (Ozkan and Ozkan, 2004).

Arguably, liquidating the assets in a stable or prosperous economy is cheaper and convenient because firms easily access the capital markets (Kim, 1998). Due to the high liquidity premium, companies should strategically hold less cash to avoid incurring a substantial amount of opportunity costs. Yet, La Porta *et al*. (2002) and Kalcheva and Lins (2007) argued that firms require to have the cash holdings policy of firms for financing investments. Practically, when the companies raise external funds from the capital market, they will be charged by many costs and faced different constraints. Because of these complexities, firms will have the probabilities of either not raising enough money for good investments or compromising the financial returns due to the high cost of capitals. Proposed by Ferreira and Vilela (2004), firms that reserve extra cash can increase their financial capitals and then use it to invest in future projects. Therefore, business organizations should have sufficient cash holdings to avoid regret by not capturing the attractive investment opportunities (Pinkowitz *et al*., 2006). In addition, the extant literature found that firms with financial constraints (Sufi, 2009), poor access to external capital (Opler *et al*., 1999), and undervalued equity (Acharya *et al*., 2007, Almeida *et al*., 2004) have a higher tendency to reserve extra cash, which provides them flexibilities to tackle the financial distress. Although firms can employ debt capacity to substitute cash holdings which protect them from liquidity risk, debt capacity is only considered as poor replacement of cash (Lins *et al*., 2010).

4.2.3 Agency Motive

According to the managerial entrenchment theory, when the shareholders of the firms are too dispersed, and managers hold little equity, managers are likely to deploy corporate actions to pursue their career and personal benefits. Due to the division of ownership and control within the company, an agency cost may arise. Regarding the agency motive, this agency cost explains properly the entrenched managers have an incentive to hold cash for their own sake but at the same time compromise the interests of shareholder (Opler *et al*., 1999). The higher agency costs, the larger amount of cash holdings. Furthermore, Jensen (1986) provided the parallel line of argument that entrenched managers have less tendency to pay out dividends and retain large cash reserves in the firms' bank accounts. Some scholars also reported cross-country evidence to indicate these cash holdings strategies (Dittmar *et al,* 2003). Despite reserving extra cash, Dittmar and Mahrt-Smith (2007) and Harford *et al*. (2008) argued further that entrenched managers spend these cash reserves in a quick fashion. Therefore, the agency motive is one of the reasons why firms reserve extra cash.

The agency problem is another possible reason to account for large debt capacity unused by firms and managers incline to hold excess cash (Blanchard *et al*., 1994, Dittmar and Mahrt-Smith, 2007, Dittmar *et al*., 2003, Harford, 1999, Harford *et al*., 2008, Kalcheva and Lins, 2007, Opler *et al*., 1999, Pinkowitz *et al*., 2006). When managers resort debt finance to obtain external funding, the managers' behaviour and actions will be constrained by these debt instruments. For example, the bank will impose covenants and scrutinise the firms' financial performance if it issues debts or commits credit lines. As a result, the entrenched managers prefer to keep a large amount of cash and reduce the level of committed credit (Sufi, 2009).

4.3 Theories of Cash Holdings

4.3.1 Trade-off Theory

Trade-off theory determines an optimal cash level that the firms should maintain by comparing the costs and the benefits to reserve extra cash (Ferreira *et al*., 2005). Managers strive to maximise shareholder wealth, and this optimal level is estimated from balancing marginal benefits and marginal costs of cash holding (Anjum and Malik, 2013). On the one hand, regarding the marginal costs of cash holdings, the firms highly concern about the opportunity cost of capital invested in cash as it only obtains lower financial returns than other investments with similar risk levels (Gao *et al*., 2013). More than that, the agency costs arising from empire-building and managerial perks may also be another potential marginal cost of cash holding (Harford, 1999). On the other hand, the cash holdings policy will provide several benefits to the firms, including minimizing the transaction costs associated with liquidating tangible or intangible assets, reducing the risk of experiencing financial distress and investing the projects without severely hindered by financial constraint conditions (Pinkowitz *et al*., 2006). No doubt that corporation organisations need to reserve a certain amount of cash to invest in attractive financial projects and pay for current expenses. If firms have not enough cash, they will hardly operate and survive in the competitive market. To acquire external financial resources, firms will resort to the capital market or liquidate their assets. Yet, these kinds of fund-raising methods may sometimes encounter difficulties or incur significant financial costs due to asymmetrical information problem. As a result, excess cash deposited in the firms saving account can be served as a buffer to avoid financial distress.

Following the propositions from Keynes (1936), Ferreira *et al*. (2005), and Mihai and Radu (2015), the trade-off theory building upon the transaction cost motive and precautionary motive could explain why businesses implement cash holdings policy. Regarding the business perspective, holding liquid assets occasionally is the costly option, particularly interest rates offered by the banks hitting the lowest historical record. Therefore, firms with excess cash holdings only obtain a lower rate of return from this liquid asset because of liquidity premium and, sometimes, tax disadvantages (Opler *et al*., 1999). Yet this opportunity cost will become less problematic when the economy experiences downturn as a firm is difficult to sell their assets in return for cash in the markets. Further, both the agency costs of debt (Bernanke and Gertler,

1989) and credit spreads (Chen, 1991; Fama, 1990) are high during the economic recession. These lead the firms to reserve excess cash and mitigate the liquidity risk. In addition, investors are usually pessimistic in the economic downturn period, and the marginal attractiveness of investments other than cash are low (Ferreira *et al*., 2005). Thus, the opportunity cost of holding cash is lower when the economy performs badly.

As mentioned previously, the precautionary motive is another driver which causes business to hold cash. This motive presents when financial attractive and positive net present value [16] (NPV) projects appear in the market, yet the firms have difficulties raise capital from the public to invest them. As a result, firms abandon these projects reluctantly because the external costs of capital outweigh the potential financial returns. To mitigate the financial distress brought by these circumstances, managers will have the precautionary motive to reserve extra cash in the firm's account and not abandon similar opportunities in the future. Furthermore, information asymmetry is a significant problem faced by firms when they access the capital market. In the real business world, managers and outside investors possess different knowledge about the firms, respectively. Because of this knowledge gap, investors may underprice the shares and securities of the firm and result in increasing the cost of external funding. In addition, the agency cost of debt is another source of problem hindering businesses to raise financial capital from the external markets. The agency cost of debt exists when there is misalign of interests between shareholders and debtholders. Generally, the higher agency cost of debt, the higher the cost of debt. Schnure (1998) found that firms with rated debt have lower cash holdings than their counterparts. On the flip side, these results suggested that agency problem hinders the firms from accessing the capital markets. These firms support their investments and business growth optimally in response to larger cash holdings. Remarkably, this agency cost will become more expensive during economic slowdowns. On the one hand, the demand of creditors is stronger, such as credit spread and collateral, to protect them from a debt default. On the other hand, the shareholders will reject positive NPV projects during economic downturn to improve the firm's survival rate and this

[16] The DCF method (namely, approach of the discounted cash flow valuation) 'values the company on basis of the net present value (NPV) of its future free cash flows which are discounted by an appropriate discount rate. The formula for determining the NPV of numerous future cash flows is shown below' (Steiger, 2008).

$$NPV = \sum_{t=0}^{n} \frac{FCF_t}{(1+r)^t}$$

, where FCF_t is future free cash flows, r is discount rate will exacerbate the interest misalignment between shareholders and debtholders. In short, the trade-off model suggested that business reserves more cash during both normal economic condition and recession (Ferreira *et al*., 2005).

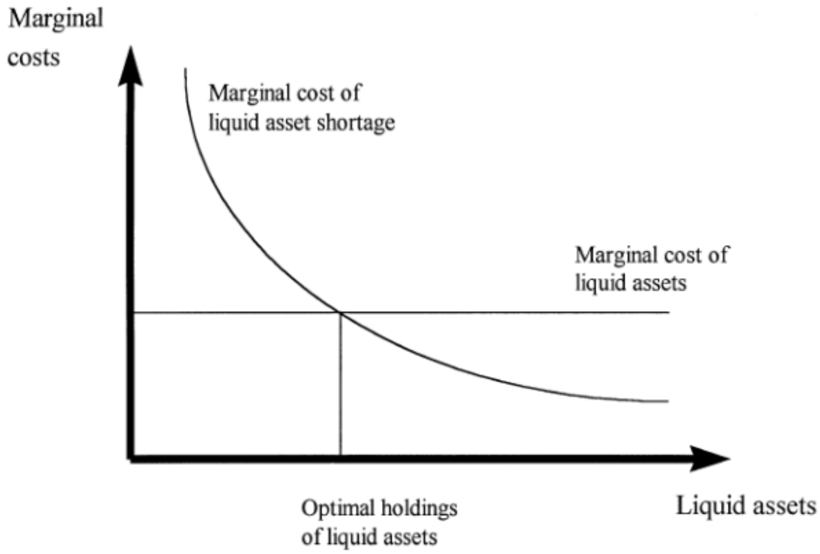


Figure 4.1 Optimal holdings of liquid assets

Source: Opler *et al*. (1999)
Note: Figure 4.1 shows, 'under Opler *et al*. (1999) assumptions, that the amount of liquid assets is given by the intersection of the marginal cost of liquid assets and the marginal cost of liquid asset shortage curves. The marginal cost curve of being short of liquid assets is downward sloping and the marginal cost curve of holding liquid assets is assumed to be horizontal. 'With the transaction costs model, the cost of liquid assets is their lower pecuniary expected return, because part of the benefit from holding liquid assets is that they can be more easily converted into cash. There is no reason to think that this cost varies with the amount of liquid assets held. If the firm has a shortage of liquid assets, it can cope with the shortage by either decreasing investment or dividends, or by raising outside funds through security issuances or asset sales. A greater shortage has greater costs, because addressing a larger shortage involves decreasing investment more or raising more outside funds' (Opler *et al*., 1999)' (Dos Santos Borges, 2016).

4.3.2 Pecking Order Theory

Contrary to the trade-off theory, pecking order theory (also known as financial hierarchy theory) suggested that there is no optimal amount of cash that the corporation should hold (Opler *et al*., 1999). According to the pecking order theory (Myers and Majluf, 1984), the corporations alter their level of cash holdings due to the demand for internal financial resources. The cash acts as the buffer and helps firms tackle the challenges between retained earnings and investment needs (Ferreira and Vilela, 2004). Therefore, cash holdings are solely the outcome after the firms make the corporate and financial investments by thorough considerations (Cruz, 2015). In its view, pecking order theory assumed that firms should use internal funds (or retained earnings) as the top priority financial source to invest in new projects. Then, the firms should turn to debt finance. Lastly, if there is no other financing option left to the businesses, they should issue equity.

Myers and Majluf (1984) laid the theoretical foundations for pecking order theory in their ground-breaking research. They argued that firms follow a designated financing hierarchy to minimise costs of asymmetric information as well as other financing costs. Further, the shareholder wealth will maximise if the managers regard the pecking order theory (Opler *et al*., 1999). Prior to seeking external money from the capital market, firms should resort to the internally possessed funding at the outset when dealing with new investment projects (Myers, 1984). Regarding the types of internal fund, they can be undrawn credit lines, cash and other liquid assets (Cruz, 2015). The rationale behind this strategy is that the cost of external financing is higher than the internal counterpart due to information asymmetry (Mihai and Radu, 2015).

In case the internal funds are in deficit condition, firms will either decrease cash reserve or use debt to access external financial resources. Under this circumstance, firms with lower cash holdings may use both safe and risky debt to invest the positive NPV projects (Ferreira and Vilela, 2004). The access to the capital market, however, is not without any difficulties. As the managers and outside investors have a different level of business knowledge about the firm's assets and true value, these will generate the cost of finance and induce firms to choose between internal and external funds (Myers, 1984). Looking at the U.S. firms from Compustat database between 1971 and 1994, Opler and Titman (1994) found that firms with high information asymmetry problem tend to hold more cash to prepare the future investments opportunities. Dittmer *et al*. (2003) also shared the same view that these firms avoid accessing external financing as their assets are undervalued by the market. Remarkably, businesses prefer to use debt rather than issue equity to raise external funding as offering new equity associates with expensive costs arises from information asymmetry (Pinkowitz *et al*., 2006). When firms go bankrupt, debtors have the first legal claim to get back the money while shareholders come second to reimburse. As with debt, firms that issue equity will also suffer the asymmetry of information. The shareholders who have the second class to claim back the money will exacerbate the cost of external financing (Kinnunen, 2015).

Although pecking order theory can explain firms reserve cash to invest in new project satisfyingly, it cannot account for the impact of business conditions on cash holdings. Generally, firms will generate more cash flow during the prosperous economic period so that they can accumulate more cash. At the same period, these firms tend to invest more by using that amount of accumulated cash, so the cash holdings decrease. Yet, this logic cannot be easily observed when the firms categorised into financial constraint conditions (Ferreira *et al*., 2005). Both financial constrained and unconstrained firms invest in the economic expansions period as the investment projects are highly likely to bring revenue. By continuing to invest in these positive NPV projects, firms can experience growth and become stronger in the market. During economic downturns, the financially constrained firms will reject a large volume of projects even though they are profitable. These firms need to reserve cash to mitigate liquidity risk or any unforeseeable adverse events over the recession times (Ferreira *et al*., 2005). Moreover, these liquidities will be used for investment when the business cycle has changed to expansion, thereby retaining less cash in bloom. However, the financially unconstrained firms are not in the same position as their counterparts because they have the better financial resource and lower liquidity risk either in the bear or in the bull market. As a result, the amount of cash holdings in financially unconstrained firms is hard to predict across the business cycles based on pecking order theory.

4.3.3 Agency Theory

Regarding the papers which discussed the topic of cash holdings, many would use the agency theory to put forward their argumentations (Cruz, 2015). As mentioned beforehand, the trade-off theory focused on weighing the marginal costs and benefits of cash holdings to determine the amount of cash holdings. Theoretically, this reserved cash should be ultimately used to maximise the shareholder wealth (Ferreira *et al*., 2005). In today business world, the management and ownership of the firms are separated in corporate governance. This separation involves the shareholders delegating the controls or powers to managers (agents) to perform their original duties. Specifically, this separation ensures the businesses leading by a team of professionals with the necessary skills and knowledge, which are essential for the firms to outcompete from their rivals. Further, the separation facilitates the maximisation of capital. The managers can perform a role as mediator between shareholders to resolve their conflicts when each shareholder has an individual investment preference. In their jobs, managers need to identify the optimal project, balance different interests, and use the financial resources efficiently to secure the highest profits among all shareholders [17]. On the flip side, the delegation generates the expensive agency cost. For example, managers have different views and opinions on the costs and benefits of cashing holdings related to the shareholders, so they have misaligned interests (Opler *et al.*, 1999). As a result, these firms may hold so much cash that they will compromise the shareholders' wealth and company profits (Anjum and Malik, 2013). Looking at the total 1952 U.S. publicly traded firms between 1990 and 2003. Dittmar and Mahrt-Smith (2007) found that the $1 held by a poorly governed firm will depreciate from 22% to 58%, while the monetary value of $1 will be doubled saved by a well-governed firm. Besides these, limited managerial ownership of the firm, compensation based on the firm size as well as managerial perquisite consumption are other types of agency problem (Nikolov and Whited, 2014).

According to the agency theory (Jensen, 1986), a manager has the discretionary power in conducting the business's cash holding policy. In general, managers tend to build excess cash balances, as it can reduce firm's liquidity risk, prepare the financial distress, and strengthen their managerial discretion. By employing the dynamic structure model and simulated method of moments, Nikolov and Whited (2014) found that the agency problem is positively associated with cash holdings. Yet, this precautionary motive will cause a manager to place too much emphasis on cash accumulation. As a result, the cash of the firm will accumulate to such a level that is not in the best interests' shareholders (Ferreira *et al*., 2005). In their study, Jensen and Meckling (1976) also suggested that the management of firms prioritizes accumulating extra cash rather than payout to its shareholders. More importantly, Jensen (1986) argued that managers with plenty of discretionary cash will use these liquid assets to pursue their own self-interest rather than enhancing the firms' value and usually spend this cash rapidly. In the model created by Jensen (1986), money is viewed as the most suitable financial asset used by entrenched managers to obtain their own benefits (Kinnunen, 2015). Despite that cash is easy to access from the business account, raising external funds will cause a lender to oversee the firm's

[17] See for example, 'The Importance of Separating Ownership And management; 3 Steps to Get Families Started', Forbes, 29 Apr 2020.

financial condition and disclose how the debt will be used. Further, another strand of literature indicates that firms located in countries with pronounced agency problems have a larger cash holding than their counterparts (Jensen, 1986). The current research also provided similar empirical evidence. By using the panel data of 11000 firms from 45 countries and shareholder protection as a proxy of the agency problem, the finding of Dittmar *et al*. (2003) indicated that corporations operated in the countries with low legal shareholder protection hold 25% more cash than the corporations located in nations who emphasize comprehensive protection. This result was robust after controlling for industry effects. In addition, La Porta *et al*. (2000) suggested that the agency problems in U.S. markets are less severe than other nations around the globe because U.S. shareholder can request firms to return the excess to them via legal channels.

While many scholars argued that the linkage between the agency problem and cash holdings is either weak or non-exist, using the sample of 89 firms publicly traded in the U.S. market which hold either high cash or equivalent (more than 25%) between 1986 and 1991, Mikkelson and Partch (2003) showed that cash holdings in these businesses are only temporarily in nature and no relation between agency problem and cash holdings is established. More than that, they contended that high cash holdings are beneficial to the firms, including faster growth rate, better financial performance, higher investment, and R&D expenditure. Bates *et al*. (2009) also suggested that the principle-agent conflict does not influence firm's cash holdings. Their results were robust and convincing by applying three methods to test the hypothesis. First, they considered the correlation between cash flow and the GIM index, which was a proxy for managerial entrenchment. Secondly, they questioned the results from the study conducted by Dittmar and Mahrt-Smith (2007), which asserted that the value of cash will decrease if firms hold too much cash. At last, they evaluated the impact of cash holdings on future growth in cash balances. All the empirical findings from Bates *et al*. (2009) pointed to one conclusion that agency theory cannot explain a firm's cash holdings satisfyingly and rationally.

4.4 The Determinants of Cash Holdings

The main theories on corporate cash holdings are trade-off theory, pecking order theory and agency theory. In trade-off theory, the optimal level of cash holdings is determined by trading off the marginal costs and marginal benefits of holding cash. There are three benefits which encourage firms to retain cash reserves. Firstly, cash holdings are a safety reserve against potential losses or external financial constraints to reduce the likelihood of financial distress. Secondly, sufficient cash holdings increase firms' financial ability to pursue optimal investment policy and allow them to invest in positive NPV project. Lastly, cash holdings are a buffer between the sources and the use of funding to reduce the costs incurred with outside funding or existing asset liquidation. The cash-holding cost consists mainly of the opportunity cost of the fund invested in liquid assets (Ferreira and Vilela, 2004).

Different from trade-off theory, the pecking order theory proposed by Myers (1984) did not set targeted cash levels and regarded cash as a buffer against the conflict between retained earnings and investment needs. Firms develop the order of financing to reduce the costs related to asymmetric information and external financing. They firstly finance their investments with retained earnings, then with debt, and finally with equity. Current operational cash flows are sufficient to invest so that firms repay debt and hoard cash reserves. In a different situation, the lack of retained earnings forces firms to spend cash holdings and issue debt.

Furthermore, the agency theory of Jensen (1986) stated that the separation of ownership and control results in the information asymmetry between managers and shareholders. Generally, these two groups of people pursuing their respective benefits which cause interest conflicts as the ultimate outcome. Managers are incentivised to accumulate cash and take control of the businesses' assets due to their discretionary power over investment decision. Cash-rich managers have sufficient financial resources to refuse external financing and conceal the firm-specific information away from the public. Therefore, investment decision making by these managers may weaken the interests of investors.

Based on the above theories on cash holdings, some important characteristics of firms, including dividend payment, growth opportunity, leverage, firm size, cash flow, cash flow volatility, capital expenditure and liquidity asset substitute, are regarded as the potential determinants of cash holdings level of the firm. Yet, the existing empirical research provided ambiguous evidence to suggest which of these firms' characteristic affect cash holdings precisely. This part discusses how firm characteristics and corporate governance system link to cash holdings.

1) Dividend Payment

In pecking order theory, in the presence of asymmetric information between firms and investors, the costs of internal financing form are the lowest (Myers and Majluf, 1984). According to this theory, the decisions of firms to payout dividend rely largely on their demand for preserving cash to increase new investments or to finance a budget deficit, not on exploiting certain tax advantages (Hill *et al*., 2014). Firms with dividend payments tend to keep large cash holdings to avoid cash shortages, especially at the time when paying dividends. (Ahmed *et al*., 2018). Looking at the international level, a positive linkage was observed in Japanese, German and Chinese markets which illustrated that firms that pay dividends hold larger cash reserves (Chen *et al.,* 2012; Hill *et al.*, 2014; Ahmed *et al*., 2018).

By contrast, from an agency perspective, dividend payout is negatively linked with cash holdings. Proposed by Easterbrook (1984), the dividend payments perform an accurate and efficient monitoring function of these firms in raising new capital from the external markets. US public firms pay out regular dividends to shareholders and lower managerial agency costs, thereby reducing cash reserves (Bigelli and Sánchez-Vidal, 2012).

Regarding the trade-off theory perspective, dividend payment and cash holdings also have existed in a negative relationship. This theory demonstrated that the optimal level of cash holdings is determined by trading off their marginal cost and marginal benefit. A rise in the cost of liquid asset shortage increases the marginal cost and thereby increases the liquidity asset holdings. Hence, a shortage problem of liquid assets in a firm is alleviated by reducing dividends or raising external capital (Opler *et al*., 1999). According to this theory, Opler *et al*. (1999), Ozkan and Ozkan (2004), and Ferreira and Vilela (2004) put forward an idea that dividend-paying firms hold less cash reserves than those without dividend payment counterparts. Firms with dividend payout cut their dividends to obtain capital at a low cost. Yet firms without dividend payments are prone to engage in external capital raising activity and cover the higher cost than those paying dividends. In this aspect, the empirical research conducted by both

Pinkowitz and Williamson (2001) and Harford *et al.* (2014) proved a significantly negative relationship between dividend payment and cash holdings in the US.

2) Growth Opportunity (Investment Opportunity Set)

Based on agency theory, the linkage between growth opportunities and cash holdings is ambiguous. On the one hand, as managers pursue their own goals at the expense of the benefits of other shareholders, the interest conflicts between shareholders and managers create a negative relation between growth opportunities and agency costs. For the firms operated by entrenched managers, sufficient cash holdings will provide them opportunities to invest in different projects unrestrictedly, even though some of these projects have negative NPV (Ferreira and Vilela, 2004; Drobetz and Grüninger, 2007). If this circumstance becomes realistic, overinvestment in negative NPV projects will cause the destruction of shareholder value. Therefore, the linkage between growth opportunities and cash reserves is inverse.

On the other hand, firms with greater opportunities but with substantial agency cost of debts tend to retain large cash reserves. For the firms which have risky debt and better growth opportunities, managers decide to forgo profitable investment projects after thorough considerations. Because of the misalignment of interests between shareholders and debt holders, high agency costs will be generated and lead to turn down the attractive investments. In this way, these firms will build extra cash holding indirectly (Myers, 1977). Retaining larger cash reserves allows these corporations to cope with the market stress from costly external funding when agency cost is high (Ozkan and Ozkan, 2004). Furthermore, firms with substantial growth opportunities face higher bankruptcy costs (Williamson, 1988; Harris and Raviv, 1990; Shleifer and Vishny, 1992), owing to the fact that these growing opportunities are intangible in nature and their values are vulnerable and unprotected during bankruptcy. Therefore, managers are more willing to hold a large amount of cash and marketable securities to reduce financial distress and bankruptcy (Ozkan and Ozkan, 2004).

Both the trade-off and pecking order theories indicate that growth opportunities positively influence corporate cash holdings. Suggested by trade-off theory, firms with constrained capital have the benefit to establish cash reserves as these holding facilitate them to pursue the optimal investment policy. In a different situation, they are forced to finance the positive NPV projects by costly external fund alternatively or may give up these valuable investment opportunities. Businesses with high growth opportunity are much more vulnerable to these circumstances. As these firms place emphasis on the profit-making projects, foregoing these investments will severely undermine their business prospects and cause them to expose financial distress (Ferreira and Vilela, 2004).

Regarding the pecking order theory perspective, some studies showed that firms with better growth opportunities prefer to hold more cash. Their central argumentations were that acquiring funds from the external markets is costly. Firms with cash shortages are no choices but reluctantly to forgo profitable investment projects. Consequently, these firms save large cash holdings indirectly (Ahmed *et al*., 2018)**.** In the circumstances where better investment opportunities accompany the greater risks of financial distress costs, firms are more willing to retaining more cash reserves to avoid these potential costs even though growth opportunities are existed (Ozkan and Ozkan, 2004; Bates *et al*., 2009; Belghitar and Khan, 2013). Furthermore, the mounting empirical findings showed a significantly positive association between growth opportunity and cash holdings (Opler *et al*., 1999; Hardin *et al*., 2009; Kim *et al*., 2011a; Chung *et al*., 2015).

3) Leverage

By studying the literature that relied upon trade-off theory, their findings in regard to the association between leverage and cash reserves are ambiguous (Ferreira and Vilela, 2004). On the one hand, this theory expected a positive association between leverage and cash reserves (D’Mello *et al*., 2008). ‘Due to the pressure that rigid amortization plans put on the firm treasury management’, high leverage amplifies the probability of the occurrence of financial distress and leads to bankruptcy eventually (Ferreira and Vilela, 2004). In general, firms with high leverage decide to retain larger cash reserves as insurance to reduce the probability of these bad events. On the other hand, if the ability to issue debt is taken into consideration, highly leveraged firms which can easily raise debt and are prone to keep less cash (Ferreira and Vilela, 2004).

Following the pecking order theory and agency theory, leverage has a negative linkage with cash holdings. Based on pecking order theory, debt usually increases when investments are in excess of retained earnings, while debt decreases when investments are lower than retained earnings. Thus, cash reserves follow an inverse pattern of this evolution (Guney *et al*., 2007; Ahmed *et al*., 2018). This linkage between cash holdings, debt and investments implies that leverage and cash holdings have a negative relation.

In addition, agency theory also expected this inverse relationship, owing to the reason that a debtholder performs the monitoring role in regulating managerial discretion, and this effect is more significant to high-leverage firms (Opler *et al*., 1999; Ferreira and Vilela, 2004). Management teams in highly leveraged companies are disciplined through debt covenants along with the requirements made by creditors. Thus, they have less discretion. Managers with less discretion cannot keep large cash reserves under their control. In contrast, managers in less leveraged companies are under less supervision which confers them greater discretionary. In these firms, managers are prone to stock up cash holdings under their control, thereby increasing their discretionary power. Mounting empirical studies established a negative linkage of cash and leverage (Kim *et al*., 1998; Guney *et al*., 2007; Harford *et al*., 2008; Hardin *et al*., 2009; Fernandes and Gonenc, 2016).

4) Firm Size

A positive relationship between firm size and cash holdings is observed in some academic papers. Following the pecking order theory, these papers illustrated that firms with high cash flow tend to keep more cash (Opler *et al*., 1999). If current operational cash flows are sufficient to invest in projects, firms are more likely to grow and be viable. Apparently, large firms have larger cash flow than small firms, and they tend to hold more cash. Additionally, agency theory also argued in the parallel line and predicted this positive relationship. Owing to their free riding problem, large firms are more likely to have superior managerial dispersion power over the firm investment decision-making and financial policy execution; hence they hold more cash reserves under their control. Because of considerable cash holdings possessed by large firms, bidders require substantial financial resources to take over these firms. Eventually, large firms are less likely to become the target of a takeover and protect them from hostility (Ferreira and Vilela, 2004).

Following the extant research, a negative association between firm size and cash reserves was established. In support of trade-off theory, Harris and Raviv (1990) suggested that larger firms are more willing to invest in different projects with growth opportunities rather than stockpiling cash (Anjum and Malik, 2013). Additionally, the models of Miller and Orr (1966), which were used to determine the optimal level of cash holdings, indicated that economies of scale are closely related to cash management. Therefore, larger firms have the tendency to retain less cash reserve than smaller firms.

Furthermore, Peterson and Rajan (2002) argued that the cost of obtaining funds through borrowing is independent of the loan size; that is, these costs are fixed. Thus, it is comparatively more expensive for small firms to raise funds, and thereby encouraging them to keep larger cash reserves than large firms (Barclay and Smith, 1996; Peterson and Rajan, 2002). The role of diversification of firms' products and services in cash management is also highlighted in this aspect (Titman and Wessels, 1988; Ferreira and Vilela, 2004; Ozkan and Ozkan, 2004). Rajan and Zingales (1995) mentioned that diversification helps firms lower their probability to experience financial distress. Large firms are easy to diversify through different means and have a low likelihood to experience financial distress (Titman and Wessels, 1988). By contrast, small firms are highly likely to be liquidated during financial distress (Ozkan, 1996; Titman and Wessels, 1988) and tend to keep more cash reserves to lessen market risk (Ozkan and Ozkan, 2004).

Lastly, as large firms have lower costs incurred with information asymmetry than small firms (Collins *et al*., 1981; Brennan and Hughes, 1991), these have the important implication that small firms are more restricted by the borrowing capacity and face higher external financing cost. As a result, they will retain large cash to combat the adverse situation (Whited, 1992; Fazzari and Petersen, 1993; Kim et al., 1998). Opler *et al*. (1999) and Ferreira and Vilela (2004) reported that firm size and cash holdings have an inverse relationship in U.S. and EMU markets.

5) Cash Flow

Trade-off theory and pecking-order theory put forward different views of the effects of cash flow on cash holdings (Ferreira and Vilela, 2004). Regarding the trade-off theory perspective, cash flow is negatively associated with a firm's cash holding level. Cash holding can be recognised as a buffer against the shocks from adverse information and increases the likelihood of survival during a market downturn. While the cash flow acts as an extra driving source of liquidity which is a substitute for cash holdings (Kim *et al*., 1998; Ferreira and Vilela, 2004). Several scholars, such as Hardin *et al*. (2009) and Duchin (2010), suggested a negative relationship between cash flow and cash holdings.

On the other hand, pecking order theory proposed that cash flow is positive related to cash holding. Under this theory, cash flow is a source of internal funds and is cheaper than costly external funds (Ahmed *et al*., 2018). Firms tend to hold a large amount of cash when their cash flow is high. Remarkably, a positive relationship between cash flow and cash holdings was recorded in majority of empirical studies (e.g., Pinkowitz and Williamson, 2001; Ozkan and Ozkan, 2004; D'Mello *et al.*, 2005; Chen *et al*., 2015; Ahmed *et al*., 2018).

6) Cash Flow Volatility

Consistent with agency theory, agency costs and financing costs are high when the volatility of cash flow is considerable (Ahmed *et al*., 2018). Thus, firms with highly volatile cash flows are more likely to be out of cash when there is an unexpected cash flow deterioration (Ozkan and Ozkan, 2004; Guney *et al*., 2007). A few empirical studies reported that cash flow volatility is negatively associated with cash reserves (Ferreira and Vilela,2004).

However, in line with the prediction of precautionary motives, trade-off theory and pecking order theory illustrated that the positive relationship should indeed exist. Theoretically, cash flow volatility reflects the degree of uncertainty about future cash flows. When the firms experience high cash flow volatility, their operations are usually challenged due to the absence of liquid assets (Ozkan and Ozkan, 2004). More than that, the businesses will suffer potential losses when cash flow volatility is high (Bigelli and Sánchez-Vidal, 2012). For instance, losses are incurred from the cost of failure related to the legal, accounting, trustee, and auction fees (Ang, 1991).

The precautionary motive for increasing cash holdings indicated that firms fear this volatility and are eventually forced to cut dividends or divest assets and get cash to avoid financial trouble.

As with the precautionary motives discussed above, trade-off theory regarded cash holdings as a safety reserve to lower financial distress and pecking order theory regarded cash holdings as 'a buffer between retained earnings and investment needs' (Ferreira and Vilela, 2004). Businesses keep large cash reserves to prepare potential valuable investment opportunities (Minton and Schrand, 1999) and simultaneously reduce the cost of liquidity constraints (namely, the cost of accessing external capital) (Ozkan and Ozkan, 2004). The majority of empirical studies showed that cash flow volatility is positive to cash reserves (Opler *et al*., 1999; Guney *et al*., 2007; Han and Qiu, 2007; Ahmed *et al*., 2018).

7) Capital Expenditure

Capital expenditure measures the tangible properties that the firm currently possessed (Hery, 2014). Capital expenditure also helps firms to increase or create new assets if guarantees are required (Bates *et al*., 2009). Additionally, it is used as collateral for additional borrowings and enhances the debt capacity, as evidence by 'the multiplier effect of new capital investment on a firm's debt capacity' (Almeida and Campello, 2007; Hahn and Lee, 2009; Chua, 2012).

Based on pecking order theory (Myers and Majluf, 1984), the relation between capital expenditure and cash holdings is ambiguous. On the one hand, capital expenditure is negatively associated with cash holdings, owing to the reason that internal financing form has the lowest cost. Capital expenditure increases firms' financial capacity and weakens the need for cash. Furthermore, it acts as collateral to secure the debt so that firms do not hold large cash reserves. The negative relation between capital expenditure with cash holding is found in Kim *et al*. (2011a) and Jinkar (2013).

On the other hand, capital expenditure is positively related to cash holdings (D'Mello *et al*., 2008). If firms have substantial investment opportunities and make a large amount of capital expenditures, they will demand greater fund to finance investment projects and cover these expenses. Under pressure from the potential risk-shifting and underinvestment problem, these firms are vulnerable to face high debt costs. Stockpiling cash reserves helps them reduce the need for costly external capital, so firms with higher investment opportunities allocate more cash.

From the precautionary point of view, capital expenditure is positively linked to cash. As the capital expenditure is regarded as the costs of financial distress or investment opportunities (Bates *et al*., 2009), firms hold cash to avoid potential underinvestment and cover capital expenditure. Therefore, firms with high capital expenditures are more likely to hold large cash reserves (Lee and Powell, 2011). The empirical evidence of Riddick and Whited (2009) supports this positive relation.

8) Liquidity Asset Substitute

Trade-off theory upheld a negative linkage between non-cash liquid assets and cash holdings. Liquid assets addition to cash and cash equivalents (such as debtors and inventories) are easily converted and provide financial benefits to firms at lower costs. Additionally, they are flexible and can be used immediately to invest the projects (Li *et al*., 2015). It is, therefore, reasonable to expect that non-cash liquid assets can be liquidated when a firm runs short of cash, so they are regarded as substitutes for cash and influence the optimal level of corporate cash holdings (Ferreira and Vilela, 2004; Ozkan and Ozkan, 2004). In short, firms have more non-cash liquid assets and hold less cash.

Overall, this part explores various firms' characteristics, such as dividend payment, growth opportunity, leverage, firm size, cash flow, cash flow volatility, capital expenditure and liquidity asset substitute. The previous literature based on three cash holding theories, including trade-off theory, pecking order theory and agency theory, demonstrated the ambiguous effects of these characteristics on the extent of cash holdings. The Summary table is shown as follow:

Variable	Trade-off Theory	Pecking Order Theory	Agency Theory
Dividend Payment	Negative (-)	Positive (+)	Negative (-)
Growth Opportunity	Positive (+)	Positive (+)	Unknown (+/-)
Leverage	Unknown (+/-)	Negative (-)	Negative (-)
Firm Size	Negative (-)	Positive (+)	Positive (+)
Cash Flow	Negative (-)	Positive (+)	N. A
Cash Flow Volatility	Positive (+)	Positive (+)	Negative (-)
Capital Expenditure	N. A	Unknown (+/-)	N. A
Liquidity Asset Substitute	Negative (-)	N. A	N. A

Note: This table summarizes the ambiguous effects of firms' characteristics on cash holdings in the previous literature, based on three cash holding theories, such as trade-off theory, pecking order theory and agency theory. The column of variable shows firms' characteristics, such as dividend payment, growth opportunity, leverage, firm size, cash flow, cash flow volatility, capital expenditure and liquidity asset substitute. Columns of trade-off theory, pecking order theory and agency show the effects of firms' characteristics on cash holdings, including positive effect (Positive (+)), negative effect (Negative (-)), not clear effect (Unknown (+/-)) and no effect mentioned in the literature (N.A), based on these three theories.

Table 4.1 Summary of the Determinants of Cash Holdings

4.5 The Effects of Excess Cash on Market Liquidity

In this research, we will investigate the relation between excess cash level and market liquidity. Following the work of Huang and Mazouz (2018), firms hoarding the amount of cash which are more than their characteristics' prediction are considered as having excess cash holding.

4.5.1 The Reasons for Investigating Excess Cash

Recent studies shifted their lights from the determinants of corporate cash holdings to the investigation of whether investors penalise firms with excess cash (hoarding cash in excess of the normal operating level). These changing attitudes are contributed by two main reasons which are the excess cash level can provide unique corporation information and money are easily wasted. Firstly, firms hoard excess cash can provide a potential indicator capturing the information about the prospects of firms above and beyond that those reflected in financial ratios, including book-to-market ratio and firm size (Simutin, 2010). Excess cash also provides information about the future raw and abnormal stock returns and the different aspects of firm performance, such as risks, investments, and profitability, but its effect exhibits in two ways. On the one hand, managers are concerned about future operating cash flow and investment opportunities, which is reflected by a large amount of excess cash. It implies that excess cash is negatively related to returns, investment, and profitability. On the other hand, firms with high external financing costs retain large cash reserves to pursue their future investment opportunities, which indicates that excess cash is positively associated with risk, future investment, and expected returns.

Empirically, recent studies on excess cash showed relatively mixed results in regard to firm performance. For example, Simutin (2010) supported the latter argument and regarded excess cash as growth options, that is, growth opportunities pertaining to a project. The findings showed that the annual return difference between the portfolios of high and low excess cash firms records as 5% or 6% after adjustment of standard three-factor risk. What is more, higher market beta in high excess cash firm indicates that these firms are at heightened risk than their low excess cash peers and thereby have higher returns. Market beta is higher, and returns are lower in cash-rich firms in declining markets. Compared with low cash peers, cash-rich firms make considerably more investment but have less strong ability to gain profit in the future.

Nevertheless, Asem and Alam (2014) documented an inverted U-shaped pattern of stock return and excess cash in the market decline and upturn. More specifically, the positive effect of excess cash on stock return is dominated at low cash levels, while the negative effect is dominated at high cash levels. This relationship depends substantially on the investors' views on the firm's future performance, hinting at the inexistence of ubiquitous investor support for cash holdings. Due to the deepening investors' concern over the firms' prospects, firms are more likely to waste excess cash on unprofitable projects during market downturns. When the level of excess cash is low, the belief that excess cash potentially mitigates the negative impacts of decreasing corporation cash flows outweighs the waste concern, leading to a positive association between stock return and excess cash. If excess cash increases over the expected operational level, the anxiety about wasting excess cash will be dominated, and the relation between excess cash and stock return turns to be inverse. This inverse relationship becomes more apparent in the firms that have growth opportunities, face poor governance structure, or suffer high information asymmetry risks. Furthermore, an overall inverted U-shaped relation with a turning point of the transiently 'positive relation dominates up to the ninth excess cash decile' is shown in the advancing market. Based on pecking order theory, the positive relation at low cash levels indicates that excess cash acts as a cheap internal source of funds for firms' growth which helps them increase returns when investors have a strong belief that firms will create enormous growth opportunities. The negative relation at high cash levels is exacerbated by the negative effects of poor governance structure or the high risk of information asymmetry. In short, the limited investors' outlook for cash reserves results in this inverted U-shaped relation.

Apart from the unique information provision, the firms will concern the entrenched managers squandering the excess cash, thereby undermining the shareholders' interests (Harford *et al.*, 2008). According to agency theory (Jensen, 1986), the conflict between shareholders and managers affects the cash holding management. For instance, self-interested managers may decide to deploy the firms' internal funds in different fashions based on their needs, such as spending free cash flow or stocking up it as cash reserves. Three hypotheses were used to explain the relation between the control of agency conflicts and firms' management. The validity of these hypotheses relies on 'managers' trade-off between current overinvestment versus future flexibility and the probability of discipline associated with each alternative' (Harford *et al.*, 2008). The flexibility hypothesis assumed that self-interested managers take 'flexibility and freedom from capital market discipline' seriously (Easterbrook, 1984; Jensen, 1986). They are more willing to stockpile cash reserves rather than spending total excess cash flow for investment, especially when the effectiveness of shareholders' control of managers is low. The spending hypothesis assumed that self-interested managers prefer corporate expansion and spend excess cash flow (Jensen and Meckling, 1976). The accumulated excess cash stimulates these managers to allocate them promptly in different ways, such as an acquisition. Hence, firms hold less cash which may weaken their capacity for future investment. The shareholder power hypothesis assumed that the shareholders control the managers effectively and permit them to accumulate excess internal funds. In fact, this extra cash is employed to lessen the underinvestment problem, which is caused by costly external capital (Stulz, 1990; Myers and Majluf, 1984). As with the spending hypothesis, the shareholder power hypothesis also implied that the agency problem is negatively related to cash reserves. The main difference between these two latter hypotheses is their prediction that better-controlled managers hold more cash in the shareholder power hypothesis while worse-controlled managers reduce cash reserves in the spending hypothesis.

The empirical findings of Harford ***et al.*** (2008) were consistent with the prediction produced by the spending hypothesis. Using governance metrics related to antitakeover provisions and inside ownership, this study showed that weakly governed US firms keep a low amount of cash. To avoid the commitments of future payout, these firms tend to repurchase their own shares rather than paying out more dividend when cash is required to distribute to shareholders. The joint effects of excess cash and weak shareholder rights lead to greater capital expenditures and undergo acquisitions frequently. Low shareholder rights and reduced excess cash reduce the firms' profitability and decrease firm value. In short, weakly controlled managers are more likely to use cash to make acquisitions and pay for capital expenditures instead of hoarding cash as an internal fund, implying that managers operated in these firms are easy to spend the excess cash wastefully.

Previous studies concentrated on the characteristics of excess cash and the effects of excess cash on firm performance and firm valuation. Based on these studies, Huang and Mazouz (2018) put a novel idea forward to the investors' perceptions of excess cash. They explored the effects of excess cash on trading continuity and liquidity risk in US stock markets. Their paper proposed that excess cash may exert two different potential effects on asset liquidity and subsequently developing two competing hypotheses. The investment opportunities hypothesis assumed that as the uncertainty of valuation relative to assets-in-place is lower with a larger amount of excess cash, the uninformed trading increases and trading costs decrease, thereby enhancing trading continuity and lowering liquidity risk. On the contrary, the management entrenchment hypothesis assumed that self-interest managers pursue their own goals at shareholders' expense. Uninformed traders have fewer interests in the firms with excess cash owing to their growing fear of expropriation. A lower level of uninformed trading increases the costs of liquidity services provision, reduces the investors' trading propensity, and grows liquidity risk.

Huang and Mazouz (2018) supported the investment opportunities hypothesis and showed evidence of a positive excess cash-stock liquidity relationship, which is stronger in the firms with the strengthened financial constraints and greater growth opportunities. Additionally, a one-unit increase in excess cash also decreases 0.489% annual equity capital cost, which hinders the nontrivial economic benefit of excess cash. Furthermore, excess cash influences firm value indirectly through its effects on stock liquidity and implies that investors are less willing to sanction or reward firms with stock illiquidity for retaining excess cash.

Consistent with Huang and Mazouz (2018), we extend the empirical analysis of excess cash and market liquidity to derivatives markets, such as equity option markets. The following two parts will systematically explain the two effects of excess cash on market liquidity.

4.5.2 The Positive Effect of Excess Cash on Market Liquidity: Investment Opportunities Hypothesis

The investment opportunities hypothesis suggested that firms with excess cash holdings are positively associated with market liquidity. From the managers' perspectives, building excess cash reserve can benefit the corporations either to avoid future operational cash flow disruption (Bates *et al*., 2009) or to prepare the financially viable investment opportunities (Simutin, 2010). The latter benefit is particularly vital to the firms' growth as extra cash hoarding can act as the cheap internal funding to finance projects and provide greater certainty to implement their future investment plans (Opler *et al*., 1999; Bates *et al*., 2009). More importantly, firms with large cash reserve have the positive impact on their stocks trading continuity because this cash holding can lower their volatility in the value of assets-in-place (Gopalan *et al*., 2012). As uninformed investors perceive businesses hoarding excess cash with lower financial risks, they have the propensity to purchase these stocks and improve trading continuity (Lin *et al*., 2009).

Simultaneously, the investors who actively engage in exchanging the stocks of firms through cash stockpiling will reduce the equities trading costs, adverse selection costs as well as market makers' inventory cost (Huang and Mazouz, 2018). These decreasing costs also provide positive feedback and entice more investors to buy or sell these stocks, thereby increasing the liquidity of these stocks. Due to their improved trading continuity, stock prices of firms with excess cash have lower liquidity risk and become more resilient to the market liquidity shock. Therefore, both the liquid premium and the cost of equity capital [18] of these stocks will decline.

Based on the extant literature, excess cash holdings are specifically essential to financially constrained firms because they allow businesses to undertake potentially profitable projects. In a

[18] 'The cost of equity capital is equal to the yield at which a firm's stock is selling, and the latter is independent of the firm's investment rate' (Gordon and Gould, 1978).

different situation, financially constrained firms subjected to the shortage of excess cash are forced to give up these projects unwillingly (Denis and Sibilkov, 2009). Compared with their counterparts that easily access external capital, financially constrained corporations often suffer from information asymmetry. When acquiring the additional capital from the market, these firms need to bear substantial transaction costs associated with borrowing (Faulkender and Wang, 2006). In this context, the excess cash holdings are valuable to the constrained firms as internal money can reduce their expenses incurred in raising external funds and result in a higher marginal value (Kim *et al.***,** 1998). According to Denis and Sibilkov (2009), firms with difficulties accessing the capital market will incline to save extra cash to maintain their normal operation and mitigate the adverse effects caused by acquiring external capital. Almeida *et al*. (2004) also provided the parallel line of argument where constrained businesses tend to stockpile more cash and prepare for the shortage of liquidity. As a result, the constrained firms will endure the underinvestment and slow growth rate problems (Denis and Sibilkov, 2009). By employing the 3SLS system of simultaneous equations, Acharya *et al*. (2007) confirmed that the significant positive association between investment and cash holdings for constrained firms is stronger than that of unconstrained counterparts. Furthermore, their research suggested that firms with high hedging needs will build a cash reserve to protect them against future cash flow shortfalls instead of seeking debt financing.

Despite hoarding excess cash can offer operational benefits to financially constrained corporations, it should be cautious that firms belonging to different cash regimes will appraise the marginal value of cash reserve variously. As Hennessy and Whited (2005) identified, there are three different regimes, including distributing cash, servicing cash, and raising cash to categorize the optimal amount of cash holdings in the businesses' capital structure.

Regarding the distributing cash regime perspectives, firms with excess cash holdings in their accountings which are more than to fulfil their short-term liabilities and invest any future value-enhancing projects are preferable to pay the funds to their shareholders via dividends or share repurchases (Faulkender and Wang, 2006). For these firms, the costs generated by the taxes and agency costs are higher than the transaction costs associated with assessing external financial capital. In the current legal system, the corporate income tax is levied at a higher rate than that of personal ones. Further, Jensen (1986) proposed that firms with excess cash reserve will experience a "free cash flow" problem and generate agency costs. Thus, investors will not highly price the marginal value of the excess cash holdings. In a similar vein, shareholders also place a lower marginal value of the cash reserve by the firms with servicing debt regime. For instance, Black and Scholes (1973) and Merton (1973) argued that the true holders of the highly leveraged company are the debtors instead of the shareholders. Therefore, the stockpiling cash will be used for debt payment and does not increase the equity value.

Opposing to the two mentioned cash regimes, firms with a raising cash regime will treasure the marginal value of cash reserve and place the value of extra one-dollar money-saving higher than $1 (Faulkender and Wang, 2006). Considering two companies that require external capital to finance positive NPV projects, their current cash reserves are low. The company, which has slightly one additional dollar of cash holdings, will face lower transaction costs than its counterparts, thereby expecting higher marginal values of cash. Specifically, financially constrained corporations are highly likely to have raising cash regime in the capital structure than their counterparts. By holding excess cash in their business accounts, constrained firms reduce the urgent need to access the capital market and minimize the associated transaction costs. In addition, Fazzari *et al*. (1988) argued that constrained firms are deterred from financing positive NPV projects because of lacking internal funding. Denis and Sibilkov (2009) also provided a similar argumentation where the level of cash holdings is positively associated with investment activities for constrained firms. As a result, the constrained firms have a greater incentive to hold extra cash to invest the potential profitability proposal that would otherwise be forgone.

Yet, increasing liquidity cannot offer such advantages to financially unconstrained businesses. This business strategy was supported by the findings of Almeida *et al*. (2004). By focusing on cash flow sensitivity, this research indicated that constrained firms have a systematically cash saving plan by taking money out of cash flow to respond to future investment opportunities and tackle costly external financing drawbacks. As unconstrained firms have easy access to the capital market, they have no such propensity which will not affect their liquidity. In short, financially constrained firms will place a higher marginal value in cash reserve to avoid the substantial transaction costs when acquiring external capital.

Despite having a greater cash retention policy is important to financially constrained corporations' survival, the research and development (R&D) firms also benefit from excess cash holdings as these internal funds compensate the substantial adjustment costs when altering the R&D project pathways and smooth their research expenditure (Pinkowitz and Williamson, 2007; Brown and Petersen, 2011). Indeed, current studies argue that firms with the largest cash reserve are in the R&D industries (Bates *et al*., 2009). Further, cash-rich R&D firms have better operational performance than their peers with lower cash balances (Mikkelson and Partch, 2003). In their findings, Brown and Petersen (2011) indicated that approximately 75% of the start-up R&D firms rely tremendously on cash reserve to smooth R&D expenses. More than that, Brown *et al*. (2009) provided robust regression results to demonstrate that R&D companies use their internal funds to limit the volatility in ongoing R&D programs and maintaining a relatively smooth flow of R&D expenses during the financial shock. Meanwhile, increasing U.S. publicly traded firms place more emphasis on their R&D investments to promote business innovation and thereby obtain a competitive edge in the future market. Sufficient corporate liquidity is particularly essential to determine whether the R&D projects can sustain or not. Additionally, R&D investments are usually associated with high adjustment costs. To be specific, R&D projects need to recruit highly skilled professionals, which subsequently involve considerable training costs and wage payment. This implies that any alternations of the R&D activities cause sizeable damages, large employees' compensation as well as potential confidential information leakage related to the innovation efforts. Because of these high adjustment costs, R&D firms with financial frictions will incline to build cash reserve as market liquidity buffers to maintain their R&D projects smoothly.

Several scholars pointed out that R&D investments are essential to long-term businesses growth (Li, 2011). Remarkably, the success rate of an R&D scheme is often determined by existing scientific knowledge and regulations (Li, 2002). More than that, the R&D financing is much less flexible than traditional capital expenditures. If the firms lack sufficient funds to conduct the required experiments, they will have no choice and suspend the R&D projects. This suspension impacts the firms' value adversely as their competitors finish the projects earlier than them. In addition, the collateral value of R&D investment is very low and makes it less attractive for capitalisation (Kothari *et al*., 2002). For instance, R&D projects are considered as risky investments because no guarantee that profitable products or technologies will be developed, and the research frequently experiences severe information problems. When these projects fail, their results will be recognised as useless and have no liquidation value. In contrast to tangible assets such as plants and equipment, they have considerable collateral value and can be used to repay the R&D firms debt. In short, the larger amount of cash holdings, the higher probability of R&D firms sustaining their innovative activities. Thus, R&D companies with large cash retention in their balance sheets provide positive signals to both informed and uninformed investors that they are competitive to develop novel products. The increased trading activities of these stocks reduce transaction costs and thereby enhance the liquidity of their equities.

1) The Positive Effect of Excess Cash on Market Liquidity: Market Volatility Analysis

Firms with large excess cash are attractive to uninformed investors. Excess cash can lead to lowers capital costs in two ways. One is the firms making efficient use of cheap capital sources (relative to equity), which help the business avoid disruption and facilitate them to develop funding certainty plans (Opler *et al*., 1999; Bates *et al*., 2009). Another is to lower liquidity premium arising from further trading participation (Huang and Mazouz, 2018). Since large excess cash is usually associated with lower volatility in the value of assets-in-place (Gopalan *et al*., 2012), then uninformed trading will be attracted and expanded. Consequently, the increased trading leads to cost reductions in inventory and adverse selection and allows market makers to supply cheaper services. Due to the lower trading costs, investors are more willing to trade in asset markets, thereby improving market liquidity (Lin *et al*., 2009).

Assets with large excess cash can be considered as low-cost and highly liquid assets. Assets with low risk and high liquidity are broadly defined as safe-haven assets when investors are concerned about the market losses (Kaul and Sapp, 2006; Flavin *et al*., 2014). In particular, investors shift their trading direction from risky assets to safe-haven assets in uncertain times (Baele *et al*., 2010). Furthermore, many uninformed investors are prone to trade in assets with safe-haven properties, such as those with large excess cash, especially in the volatile period. Therefore, due to the investors' preference for safe-haven assets, the positive effects of excess cash on option liquidity are more significant during the period of market stress.

Additionally, excess cash lowers both adverse selection and inventory costs. These cost reductions enhance firms' risk-bearing capacity to relax their risk management and mitigate the negative shocks from market risk. Cash-rich firms strengthen their capacity to reduce market risk, bring high stability as well as increase market liquidity in the market downturn. As a result, the positive effect of excess cash on market liquidity would be even stronger during the volatile period.

What is more, holding larger excess cash can hinder the occurrence of flight to liquidity in the asset markets. Based on the theoretical models of Stoll (1978) and Grossman and Miller (1988), 'flight to liquidity' is an increasing trend in the liquidity difference between high-volatility and low-volatility assets with the deterioration in the dealer capital. The reason behind this phenomenon is that under the pressure of the worsening dealer capital, traders supply liquidity mostly in assets that do not require intensive capital (assets with low volatility and lower margins). Large excess cash provides sufficient fund for firms to trade in the asset markets. It lessens the negative impact of increasing margin, so the occurrence of flight to liquidity fluctuates down gradually in the asset markets (Brunnermeier and Pedersen, 2009).

In short, excess cash helps firms to reduce both adverse selection and inventory risk and makes assets to be safe-haven. It also boosts economic resilience and lessens the occurrence of flight to liquidity. In the volatile market, the positive effect of excess cash on option liquidity becomes stronger and significant.

2) The Positive Effect of Excess Cash on Market Liquidity: Investor Sentiment Analysis

In his study, Liu (2015) used both direct and indirect measures of investors' sentiment to examine how people emotion influences the time-series variation in stock market liquidity. Regarding the direct measure, the index of investor intelligence and the index of the American Association of individual investors are used as a proxy for institutional investor sentiment and individual investor sentiment, respectively. For the indirect measure, the Baker and Wurgler (2006) sentiment index (BW index) is employed as it associates with market liquidity weakly. Their findings indicate that investor sentiment is positively associated with stock market liquidity among all three measures. In the theoretical aspect, noise trading is the primary determinant of asset market liquidity. Defined by De long *et al*. (1990), investor sentiment is the noise traders' irrational expectation related to future price by either a positive or a negative amount. The model developed by Liu (2015) revealed the demand of noise traders is driven by their sentiment. His research evidence pointed out that higher sentiment leads to larger uninformed trading volume and concluded that there is a positive linkage between investor emotion and liquidity.

Despite the above proxies for investor sentiment, the extant literature employed the ratio of put-to-call traded volume as another measure of emotion (Simon and Wiggins, 2001; Kanas, 2012). Houlihan and Creamer (2019) mentioned that the put to call volume ratio not only reflects investor sentiment and expected price fluctuations, but also indicates the direction of the bullish/bearish market. Higher values of the ratio indicate that more put options being bought relative to call options. In this case, investors perceive the market as bearish and expect the asset prices will fall soon. While lower values of the ratio imply that fewer put options being bought relative to call options. Hence, investors become more bullish and foresee the asset price rising in the future. Following the argumentation of Verousis *et al*. (2016b), on the one hand, bearish investors anticipate asset price to fall and prefer put trading to call trading. Expecting negative option prices seem to lessen trading and reduce option liquidity. On the other hand, bullish investors predict asset price to rising and are more likely to trade in calls. Under these circumstances, expected positive option prices seem to induce more trading and increase option market liquidity. In their findings, Simon and Wiggins (2001) argued that the dissemination of good news attracts massive cash investment to the stock markets and alters the investor's emotion during the bear period, thereby increasing asset prices. Corporations with substantial cash reserves can be regarded as positive news in the bear market as capitalists apprehend these cash holdings which can protect firms from uncertain economic environment and provide investment opportunities to them. Therefore, investors' emotion will reinforce the positive association between excess cash holdings and asset market liquidity.

4.5.3 The Negative Effect of Excess Cash on Market Liquidity: Management Entrenchment Hypothesis

On the contrary to the above studies, the management entrenchment hypothesis expresses a different standpoint and proposes that the relationship between excess cash and asset market liquidity exists in negative nature. The central argumentation of this hypothesis is that firm with excess cash holding will create agency problem and become less attractive to the investors. Thus, the stock liquidity of this firm will decline. More importantly, the agency problem will exacerbate when the firm size is large and with weak governance because managers who operate in these firms will spend money wastefully on fixed capital and acquisitions (Harford, 1999). In his analysis, Jensen (1986) indicated that the genuine motivation of managers to hold excess cash is to pursue their self-interests and objectives at the expense of shareholders' value. Due to the occurrence of agency conflicts, the gap of information asymmetry between managers and investors will enlarge. As a result, substantial transaction costs will be involved in trading these firms. More than that, these firms usually disclose the opaque financial report to cover up their behaviour and have an ineffective corporate governance mechanism to monitor the managing directors (Ball, 2006). Under this circumstance, it is difficult to discipline managerial misconduct. Numerous studies provided empirical evidence to support the agency cost view (Harford, 1999; Dittmar and Mahrt-Smith, 2007; Harford *et al*., 2008). Furthermore, minority shareholders are particularly concerned about this agency problem as they are more easily controlled and expropriated by managers (Johnson *et al*., 2000). Because of the threat of expropriation and wealth destruction, investors may avoid funding the companies with excess cash reserves. Consequently, these stocks will expose higher liquidity risk and more vulnerable to the market liquidity shock. To re-divert financial capital to the stocks of corporations that hoard excess cash, a higher liquidity premium is required to entice investors and increase the cost of equity capital (Huang and Mazouz, 2018).

Consistent with the view of the agency cost problem, Denis and Sibilkov (2009) provided empirical evidence to show that some financially constrained firms have low cash holding even though they recognise cash reserve is important to their business developments. Their arguments laid on the foundation where entrenched managers routinely spend the firms' cash holdings inefficiently, thereby board of directors reduce the reserve and avoid detrimental financial outcomes. In other words, maintaining higher cash balances in these financially constrained firms will ultimately lead to empire-building overinvestment (Denis and Sibilkov, 2009). Despite the agency cost perspective, Chen *et al*. (2012) also suggested that the low cash reserve of constrained firms may be contributed by their weak financial conditions. Therefore, it is extremely difficult for these corporations to accumulate cash into their business accounts. Not only will the financially constrained firm suffer the agency cost problem severely but also the R&D intensive corporations (Himmelberg and Petersen, 1994; Hall and Lerner, 2010). Following the argumentation of the Association for Investment Management and Research (1993), there is a lack of compelling evidence to conclude that the firms' future benefits are closely related to the costs incurred in R&D investments. Thus, the financial information related to R&D expenditure is arguably very relevant to firms' valuation process and creates an asymmetrical problem between investors and firms. Despite the fact that the future interests from R&D investments are extremely uncertain, the low value of the collateral value of R&D projects will make these firms unattractive to capitalisation. The negligible collateral value of R&D intangible assets is caused by either limited utilisations of the product or the liquidation value of the failure projects is worthless (Kothari *et al*., 2002). Contrary to the normal capital expenditures, R&D investments are supervised strictly by both financial and scientific regulations (Li, 2011). Because of this complex scrutinisation, investors may give up financing the R&D projects and lead these firms to suspend their research projects reluctantly. These suspensions have important implications for the R&D firms' values because they cannot complete their projects earlier than their competitors and destroy their future profitability (Li, 2011). Therefore, R&D intensive businesses usually hold extra cash to maintain normal operations as their stocks have low liquidity in the trading markets.

This part presents the investment opportunities hypothesis and management entrenchment hypothesis (Huang and Mazouz, 2018). The investment opportunities hypothesis indicated that larger excess cash reserves reduce the uncertainty of valuation relative to assets-in-place, which attracts uninformed trading and lower trading costs. Hence, market liquidity increases. In particular, as uniformed trading increases considerably in the highly volatile market (Brunnermeier and Pedersen, 2009) or during a higher sentiment period (Houlihan and Creamer, 2019), the positive effects of excess cash on market liquidity become more significant. By contrast, the management entrenchment hypothesis assumed that self-interest managers engage in cash hoarding activities with the intention of personal interest or at the expense of shareholders. Uninformed traders are less likely to invest in cash-rich firms in fear of expropriation. Reduced uninformed trading pushes up the costs of liquidity services provision and lessens the investors' trading propensity, thereby decreasing market liquidity. According to these two hypotheses, we will empirically analyse whether the relationship between excess cash and equity option market liquidity is positive or negative.

Chapter 5 Empirical Analysis of Excess Cash and Equity Option Liquidity

5.1. Introduction

Equity options remain an important instrument for investment and risk management purposes. They are useful because the option markets allow high leverages (See Black, 1972) and their prices contain predictive information about the underlying stock prices (See, for example, Cremers and Weinbaum, 2010). Finance researchers have spent considerable efforts to explore the determinants of option market liquidity. In particular, the liquidity in option markets is affected by the liquidity of the underlying stocks (Cho and Engle, 1999; Muravyev and Pearson, 2020), inventory risk (Wu *et al.*, 2014), information asymmetry (Cao and Wei, 2010), insider trading (Biais and Hillion, 1994; Augustin *et al.*, 2019) and investor sentiment (Verousis *et al.*, 2016b).

In this study, we document another source that explains the variations in option market liquidity across stocks: the level of corporate cash holdings. Our analysis is motivated by the literature that emphasizes the information content of corporate cash reserves. According to Simutin (2010), the level of cash reserve in excess of what can be explained by firm characteristics contains valuable information about the prospects of the companies and predicts stock returns. Excess cash matters because it captures firm's growth options (See Simutin, 2010), reflects an ability to invest higher and generate more profit (See Mikkelson & Partch, 2003), or to cushion firms from adverse future cashflow shortfall (See Bates *et al.*, 2009). Our study examines two competing theoretical predictions about the link between excess cash and market liquidity. On the one hand, Gopalan *et al*. (2012) suggest that higher excess cash attracts uninformed traders and helps reinforce market liquidity. As Lin *et al*. (2009) indicate, higher excess cash reduces adverse selection problems driven by the uncertainty about firm valuations; and therefore, these reductions encourage market makers to provide competitive quotes and to enhance liquidity. For these reasons, the following hypotheses will be tested:

H_1: Higher level of excess cash increases option liquidity.

H_2: Excess cash further increases option liquidity in the firms with a higher degree of information asymmetry.

On the other hand, theories developed by Ball *et al*. (2000) and Ball (2006) suggest that market liquidity decreases in excess cash as investors avoid agency conflicts and poor investment prospects associated with firms with higher excess cash. Despite the evidence in the secondary stock markets (See, for instance, Huang and Mazouz, 2018), little is known about the empirical relation between the level of corporate cash reserve and the trading activities of equity options. For these reasons, the following hypotheses will be tested:

H_3: Higher level of excess cash decreases option liquidity.

H_4: Excess cash further decreases option liquidity in the firms with more severe agency conflict problems.

Our study focuses on equity options due to the importance of the instrument in financial markets. The World Federation of Exchanges (2019) reports that the equity option is the most actively traded equity derivatives product and accounts for more than 32 percent of the total equity derivatives trading volume. According to the Options Clearing Corporation[19], equity option markets experience substantial growth in trading volume in recent years as the daily trading volume nearly doubles from less than 15 million contracts in 2015 to more than 28 million contracts in 2020. An analysis performed by Goldman Sachs (See, Goldman Sachs, 2020) indicates that the trading volume of single stock options has already exceeded that of the underlying common stocks in 2020. Option contracts are adopted by companies, asset managers, proprietary trading firms, and increasingly, by retail investors who are trading options instead of the underlying securities[20]. The previous literature (See Massa and Simonov, 2006; Seasholes and Zhu, 2010, Doskeland and Hvide, 2011) suggests that uninformed investors including many retail investors recognize their informational disadvantages when trading against better informed traders. They often tilt their portfolio away from assets subject to a greater degree of information

[19] The Options Clearing Corp (www.theocc.com /Market-Data) and *Wall Street Journal,* Jul 24 2020.
[20] Anecdotal evidence reported by the Wall Street Journal shows that a large number of retail investors are contributing to the surge in trading volume of equity options (See *Wall Street Journal* "Free Trades, Jackpot Dreams Lure Small Investors to Options", Jul 24 2020; *Wall Street Journal* "How Options-Market Amateurs Might Have Tripped Up Big Tech", Sep 4 2020).

asymmetry, and consequently, this portfolio choice affects the liquidity of these assets (See Ding and Hou, 2015). Because higher excess cash attracts uninformed traders via the reductions in adverse selection costs, following Lin *et al*. (2009), we expect that the link between excess cash and market liquidity would also be relevant in the option markets. We also predict that this relation will become more significant at times of high uncertainty about the prospects of firms, such as during the financial crisis or periods of high macroeconomic uncertainty.

Our empirical study uses the equity option data obtained from Option Metrics over the period from Jan 3, 2005 to Aug 31, 2015. This database provides details of individual option instruments including the underlying stock prices, the exercise prices, maturity dates, option interests as well as the implied volatility and the option exposure variables, i.e., the Greeks measures. We supplement the option data with the equity data provided by the Centre for Security Research (CRSP) over the same period. This database contains the daily closing bid and ask prices, the trading volume, the number of shares outstanding, and the unique security identification that allows stock price data to be matched with the option data.

Our study finds a host of interesting results. Controlling for various alternative sources of option liquidity, we show that excess cash reinforces option market liquidity. Companies with a higher level of excess cash experience a significant reduction in the proportional bid-ask spread of their stock options, higher option trading volume or greater option interests. Specifically, a rise of 1% in excess cash holding leads to a 0.58% decrease in option bid-ask spread and the relation is significant at a one percent level. We find the importance of excess cash to market liquidity is stronger for companies subject to a higher degree of information asymmetry or during the financial crisis and periods of significant economic uncertainty. This result is consistent with the argument that excess cash reduces adverse selection problems and improves market liquidity via the concentration of uninformed traders. We show that the impacts of excess cash on option market liquidity remain robust once controlling for the various effects, including investor sentiment, agency conflicts, or the endogeneity between cash reserve and option market liquidity.

Our paper contributes to the growing literature on the link between corporate cash reserves and the trading activities of corporate securities in financial markets. There remain two contrasting theories in explaining the relation between excess cash and asset market liquidity. Gopalan *et al*. (2012) show that higher excess cash improves market liquidity due to the reduction in adverse selection problems caused by the uncertainty in asset value. This theoretical prediction is consistent with the pecking-order theory (See, for instance, Myers and Majluf, 1984; Mihai and Radu, 2015) highlighting the importance of cash holdings in corporate finance because cash reduces adverse selection costs associated with capital raising. Alternatively, theoretical predictions by Ball *et al*. (2000) and Ball (2006) indicate a negative link between excess cash and stock market liquidity. Based on an agency theory, they suggest that excess cash might be accumulated by companies with poor investment prospects or a high degree of agency conflicts. Since investors try to avoid these problems, market liquidity decreases in excess cash. Our empirical results reinforce the theories put forth by Gopalan *et al*. (2012) that excess cash positively affects option market liquidity. We show that this relation is stronger for companies with a high degree of probability of informed trading or during periods of significant macroeconomic uncertainty.

Our paper is also relevant to market participants and financial regulators. Financial market participants are particularly interested in the links between corporate cash holdings and asset prices. Recent developments associated with the coronavirus pandemic in 2020 highlight the importance of cash reserves at times of crisis[21]. Studies by the regulators (See, for instance, Bank of England, 2020) show that the lack of cash surplus faced by businesses could lead to a liquidity shortfall that affects financial stability and that this condition requires urgent and significant policy responses. Our study provides further empirical support for the link between corporate cash reserve and financial market liquidity. To the best of our knowledge, our paper is the first to document the relation between excess cash and liquidity of equity options. We show that excess cash is a significant determinant for liquidity of financial options in addition to other established determinants of option market liquidity.

[21] These developments are well documented in the financial media. See, for instance, *Financial Times* "Crisis reminds Silicon Valley that cash is king", Apr 10 2020; *The Economist* "Why cash has been piling up during the pandemic", Apr 13, 2020; *Reuters* "Pandemic survival plans: U.S. businesses scramble to conserve cash, boost liquidity", Apr 14 2020; *Bloomberg* "Corporate America is stockpiling cash before Covid winter hits" Nov 11 2020.

The rest of the paper is organized as follows. Section 2 describes the empirical methodology. Section 3 explains the data. Section 4 shows the empirical evidence, Section 5 present results from the robust checks. The final section concludes.

5.2 Empirical Methodology

This study examines the linkage between excess cash and option liquidity. We first introduce different measures to capture option market liquidity and then propose an empirical framework to measure the impacts of excess cash holding on option market liquidity.

5.2.1 Measurement of Option Liquidity

Market liquidity often involves different dimensions that are not easily captured into a single number. Therefore, following Chordia *et al.* (2000), we use three measures to account for option market liquidity in this study. The first measure is the proportional bid-ask spread of financial options. Following Liu (2006), we compute option proportional bid-ask spread as the average value of the difference between ask and bid prices, divided by their mid-quote price of the option contract. An increase in the bid-ask spread indicates lower liquidity, and vice versa.

The second measure of liquidity is the trading volume. Similar to Mayhew (2002), we obtain the sum of the trading volume for all option contracts across all the strike prices and across all expiry dates for each underlying stock. Higher option trading volume suggests a rise in market liquidity.

The final liquidity measure is the option open interest. As explained in Cao and Wei (2010), option open interest is computed as the total open interest of options for each underlying stock each year. We aggregate the option interests for all option contracts across all strike prices and all expiry dates for each stock. To capture the non-linear effects of trading volume and option interests on market liquidity, we use the natural logarithm of these variables as proxies for liquidity. Option liquidity is positively related to the trading volume and the level of open interest.

5.2.2 Measuring Excess Cash Holding

Following the previous literature (for instance, Asem and Alam, 2014), we obtain the level of excess cash for each firm in each year based on the residuals from the following cross-sectional regression model:

$$Cash_i = \alpha_0 + \alpha_1 CF_{it} + \alpha_2 LEVER_i + \alpha_3 MTB_i + \alpha_4 Size_i + \alpha_5 NWC_i + \alpha_6 CAPEX_i + \alpha_7 DIV_i + \alpha_8 RND_i + \alpha_9 INDSIG_i + \varepsilon_i \quad (1)$$

where $Cash_i$ is the natural logarithm of cash and short-term investments divided by net assets for stock *i*; *CF* is earnings after interest, dividends, and taxes, but before depreciation divided by net assets; *LEVER* is the ratio of total debt to net assets; *MTB* is the ratio of market value of assets to total assets; *SIZE* is the natural logarithm of net asset value; *NWC* is the ratio of net working capital (net of cash) to net asset value; *CAPEX* is the ratio of capital expenditure to net asset value; *DIV* is a dummy variable with a value of one if the firm pays dividends, and zero otherwise; *RND* is the ratio of research and development expenditures to sales; *INDSIG* is industry cash flow risk, calculated as the mean of the ratio of the standard deviations of cash flows to the total assets in 10 years for firms in the same industry[22]. The exponential form of the residual ε_i is calculated as firm *i*'s excess cash (*ECash*). An increase (decrease) in the residual shows that cash holding in each firm is greater (less) than expected. We perform the regressions across all firms on an annual basis from Jan 3, 2005 to Aug 31, 2015. Following previous studies (See, Huang and Mazouz, 2018), we rank the residuals across the firms in each year increasingly and remove observations with the residual ε_i falling below the 1st or above the 99th percentile of the residuals.

5.2.3 Excess Cash Holding and Option Liquidity

After measuring the degrees of market liquidity and excess cash holding, we turn our attention to the effects of excess cash holding on option market liquidity. We analyze this relationship in a regression model as follows:

$$OPLIQ_{i,t} = \alpha + \beta_c ECash_{i,t-1} + \gamma Z_{i,t-1} + YR + IND + \phi_{i,t} \quad (2)$$

where $OPTLIQ$ indicates option liquidity for firm *i* at time *t*. Option liquidity variables include the proportional bid-ask spread (*OBAS*), the natural logarithm of total option volume (*OVOL*)

[22] We use the Standard Industrial Classification code to classify firms into industry groups.

and the natural logarithm of total open interest (*OI*). ECash denotes excess cash holding and $\phi_{i,t}$ is a residual error term. Year and industry dummy variables, YR and IND, respectively are contained in these regressions to control for their potential fixed effects. $Z_{i,t-1}$ represents a vector of control variables. Following previous studies (e.g. Lin *et al*., 2009; Ng, 2011), the control variables include market-to-book ratio (*MTB*) scaled by sales, firm size (*SIZE*), leverage (*LEVER*), a dummy variable for dividend payers (*DIV*), capital expenditures (*CAPEX*), research & development expenses (*RND*) scaled by sales, the level of stock price (*PR*), the changes in stock prices (*RET*), the number of shareholders (*NSHAR*) and stock proportional spread (*SBAS*)[23]. To avoid the endogeneity problem, we use the previous year details of the control variables in the regression. We perform the regressions across all firms and adjust the standard errors for the double clustering by firm and year.

This study also examines the role of information asymmetry in the relation between excess cash holding and option liquidity. Following the previous literature, we use the probability of informed trading (PIN) developed by Easley *et al*. (2002) to capture the degree of information asymmetry[24]. Previous studies (See, for instance, Hu, 2014; Goyenko, 2015) suggest that an increase in the probability of informed trading will induce greater adverse selection costs for option dealers, making them more reluctant to provide liquidity. We expect that the impacts of excess cash on option liquidity are stronger for firms with a higher degree of information asymmetry because investors congregate to firms with higher excess cash to avoid valuation uncertainty and adverse selection costs. Following the previous studies (e.g., Atilgan, 2014, Tang and Xu, 2016, Chen *et al*., 2019 and Lin *et al*., 2018), we use a dummy variable *PINDUM*, which equals 1 if the probability of informed trading (PIN) is above the annual median value across firms and zero otherwise. We analyse the role of information asymmetry in a regression model as follows:

$$OPTLIQ_{i,t} = \kappa_0 + \kappa_1 * ECASH_{i,t-1} * PINDUM_{i,t-1} + \kappa_2 * ECASH_{i,t-1} + \kappa_3 * PINDUM_{i,t-1} + \gamma * X_{i,t-1} + YEAR + INDUSTRY + \nu_{i,t} \quad (3)$$

[23] The definition of these variables contained in these regressions are shown in Appendix.

[24] We obtain the annual PIN data over the period from 2005 to 2010 from Stephen Brown's website (/scholar.rhsmith.umd.edu/sbrown/pin-data). The PIN measure is estimated using the method developed in Venter and de Jongh, D. (2006).

where subscription *i* and *t* indicates firm and year, respectively; $OPTLIQ_{i,t}$ indicates option liquidity measures.

In addition to the probability of informed trading (PIN) measure, we also use the degree of insider trading to capture the level of information asymmetry across firms. The previous literature (See, for instance, Ball, 2006) shows that corporate insiders often have superior private information about the firm fundamentals, and hence, trading by corporate insiders might exacerbate information asymmetry problems, and therefore, affect market liquidity. Following previous empirical studies (See, Ozkan and Ozkan, 2004; Harford *et al.,* 2008; Chung *et al.,* 2010; Alam *et al.,* 2019), the degree of insider trading is defined as:

$$Insider_{i,t} = \frac{InsiderShare_{i,t}}{TotalShare_{i,t}}, \tag{4}$$

where $InsiderShare_{i,t}$ is the total number of shares traded by insiders (namely, executive directors), $TotalShare_{i,t}$ is the total number of shares outstanding for firm *i* at time *t*. We obtain insider trading details from the ISS Director data[25] over the period between Jan 1, 2009 to Aug 31, 2015. We include the rate of insider trading in the model (2) as follows:

$$OPTLIQ_{i,t} = \kappa_0 + \kappa_1 * ECASH_{i,t-1} * Insider_{i,t-1} + \kappa_2 * ECASH_{i,t-1} + \kappa_3 * Insider_{i,t-1} + \gamma * X_{i,t-1} + YEAR + INDUSTRY + \nu_{i,t} \tag{5}$$

We perform the regressions over the whole sample period and adjust the standard errors for clustering by firm and year.

5.3. Data

This study uses daily equity data provided by the Center for Research in Security Prices (CRSP) and the equity option data by OptionMetrics over the period from Jan 3, 2005 to Aug 31, 2015. The CRSP database provides daily closing prices, bid and ask prices, and the number of shares outstanding. Following Asem and Alam (2014), we focus on publicly listed U.S. industrial firms and exclude utilities and financial stocks (that is, companies with the Standard Industrial Classification (SIC) falling between 4900 and 4999, and between 6000 and 6999). Following the previous literature, we analyze firms with market capitalization greater than 3.5 million U.S dollars and stocks with share prices falling between 5 and 1000 U.S dollars to avoid

[25] Details of the ISS Director data could be found via the URL link (www.issgovernance.com/esg/director-data/).

potential bias from the small firm effects. We also exclude firms with negative assets, negative sales, and those with annual assets or sales growth larger than 100% to reduce the outlier effects (Huang and Mazouz, 2018). Following Hameed *et al*., (2010), we remove daily stock observations with the quoted bid-ask spread (ask price minus bid price) greater than 5 U.S dollars or days without trades or closing stock price. Based on the above criteria, we analyze a sample of 893 firms over the sample period.

The equity option database by OptionMetrics includes daily details about the call and put option prices, the strike prices, the option interest, trading volume and the expiry date. Following the previous literature, we prepare the option data as follows: we exclude observations with zero trading volume or prices (following Cao and Wei, 2010) and remove the observations with the bid-ask spread greater than 5 U.S dollars or negative (See Byun and Kim, 2016). Moneyness is defined as the option excise price divided by the underlying stock price (See Cao and Wei, 2010). Following Simonato (2016) and Wei and Zheng (2010), we analyze financial options with a maturity of less than six months and those with moneyness within the range of [0.9, 1.1]. We compute the daily option bid-ask spreads for all individual options and use an equal weight scheme across all option contracts of the same underlying to obtain the daily average option bid-ask spread for a common stock[26]. The trading volume and open interest of a stock are aggregated across all option contracts of the same underlying security on a daily basis.

In addition to the daily stock and equity option data, we also use the Compustat database provided by Capital *IQ* over the same sample period. Using the stock identification number, we extract details related to the level of cash holding, net asset values, research and development expenses, and capital expenditures for the firms in our samples.

Table 5.1 displays the summary statistics of the firm characteristics and liquidity measures computed across 893 firms over the whole sample period. The average ratio of cash holding to net asset is 0.33 and the standard deviation of the ratio is 0.48. The average bid-ask spread of the underlying stock is 9.02 basis points. Consistent with the observation in Cao and Wei (2010),

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[26] Section 5.2 assesses the sensitivity of our results with different weighting average schemes and finds the results remain qualitatively unchanged.

option bid-ask spread is much larger than that of the underlying stocks. The average option bid-ask spread is 22.18 percentage points ranging from 1.54 to 140.63 percentage points. The log of open interest is 12.24 and the log of option volume is 10.31.

Variable	No. Firms	Mean	Median	StdDev	Max	Min
CASH	893	0.33	0.17	0.48	5.95	0.003
ECASH		0.01	0.15	1.02	4.28	-4.09
MTB		0.39	0.10	0.88	10.57	0.002
SIZE		7.46	7.43	1.53	11.82	2.56
LEVER		0.25	0.21	0.25	4.82	0
DIV		0.46	0	0.50	1	0
CAPEX		5.36	4.14	4.23	29.22	0.48
RND		0.10	0.03	0.34	10.96	0
PRICE		0.40	0.32	0.37	5.39	0.002
RET		1.34	1.39	3.65	39.42	-22.78
NSHAR		0.72	0.66	2.25	7.77	-5.52
SBAS		9.02	7.96	6.22	79.53	0.94
OBAS		22.18	18.95	15.57	140.63	1.54
OI		12.24	12.63	3.13	19.44	1.39
OVOL		10.31	10.60	2.82	18.04	0.69
SENTIMENT		0.95	0.88	0.96	31.50	0.02
PIN	675	0.09	0.09	0.03	0.26	0
NONEX	550	0.81	0.83	0.10	1	0
INSIDER	547	1.72	0.10	9.19	287.67	0

Notes: This table shows the descriptive statistics of firm characteristics and option liquidity from Jan 3, 2005 to Aug 31, 2015. CASH includes cash and short-term investments scaled by net assets; ECASH is the residual obtained from the regression equation (1), MTB is the ratio of market value of assets to total assets on a basis point; SIZE is the natural logarithm of net assets; LEVER is the ratio of total debt to net assets; DIV is a dummy variable with a value of one if the firm pays dividends, and zero otherwise; CAPEX is 100 times the ratio of capital expenditures to net assets; RND is the ratio of research and development expenditures to sales; PRICE is the stock price divided by 100; RET is 100 times the stock return; NSHAR is the natural logarithm of the ratio of common shareholders to ordinary shareholders, SBAS is proportional bid-ask spread (in basis points). Option liquidity measures are: OBAS is option proportional bid-ask spread (in percentage points); OVOL is the log of option volume (million); OI is the log of open interest (million); PIN is the probability of informed trading; NONEX is the ratio of the number of independent director and total board directors. As share outstanding is scaled by 1,000 in CRSP database, INSIDER is one thousand multiplied by the ratio of the total number of shares traded by insiders (namely, executive directors) to the total number of shares outstanding. NONEX and INSIDER variables are computed based on details obtained from the ISS Director data over the period between Jan 1, 2009 to Aug 31, 2015. The definitions and sources of the variables are reported in Appendix.

Table 5.1 Descriptive Statistics

5.4 Empirical Results

We first present the regression results to capture the excess cash measure. We then illustrate the effects of excess cash on option liquidity and study how these effects vary during the financial crisis, when volatility increases or whether they are affected by information asymmetry, investor sentiment or agency conflicts.

5.4.1 Excess Cash Holding

Table 5.2 shows the average coefficients and the *t*-statistics (in parentheses) of the regression (equation 1) used to capture excess cash holding [27]. Similar to the results displayed in Asem and Alam (2014), we observe that earnings (*CF*), the research and development expenditures (*RND*), and industry cash flow risk (*INDSIG*) could explain the ratio of cash holding to net assets. Thus, firms that are more profitable, more participated in research and development activities, or those more exposed to industrial cash flow fluctuations, are more likely to hold more cash. In addition, firm size, leverage ratio and the level of working capital also influence the degree of cash holding. Larger size companies or those with greater leverage and larger working capital tend to hold a smaller level of cash holding. These effects are significant at one percent level. The R-square obtained from the regression's averages 37 percent, a value higher than one obtained in Asem and Alam (2014).

[27] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the annual results from the VIF analysis of the independent variables in the regressions is 1.56, indicating that our results are not significantly affected by multicollinearity problems.

	Dependent variable: Cash
CF	1.29 (4.11) ***
LEVER	-0.32 (-1.58)
MTB	0.31 (3.95) ***
SIZE	-0.43 (-8.99) ***
NWC	-1.33 (-4.89) ***
CAPEX	-0.17 (-0.11)
RND	1.52 (5.66) ***
DIV	-0.16 (-1.27)
INDSIG	6.42 (2.65) ***
CONSTANT	0.89 (2.25) **
Observations	573
RSQ	0.37

Note: This table shows the mean coefficients and the mean *t*-statistics (in parentheses) of the regressions (1) estimated over the sample period from Jan 3, 2005 to Aug 31, 2015. The dependent variable, CASH, is the natural log of cash and short-term investments scaled by net assets; CF is earnings after interest, dividends, and taxes, but before depreciation scaled by net assets; LEVER is the ratio of total debt to net assets; MTB is the market value of assets divided by total assets on a basis point; SIZE is the natural log of net assets deflated in 1994 dollars; NWC is the net working capital (net of cash), scaled by net assets; CAPEX is capital expenditures scaled by net assets; DIV is a dummy variable which equals one if the firm pays dividends and zero otherwise; RND is the research and development expenditures scaled by sales; INDSIG is industry cash flow risk, defined as the mean of the ratio of the standard deviations of cash flows to the total assets over 10 years for firms in the same industry (by 2-digit Standard Industrial Classification code). We use the previous year details of the control variables CF, LEVER, MTB, SIZE, NWC, CAPEX, DIV, RND, and INDSIG in the regressions. We perform the regression model (1) each year over the sample period and obtain the level of excess cash for each firm on an annual basis. Observations are the average number of firm-level observations in each year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 5.2 Measuring Excess Cash Holdings

Table 5.3 shows Pearson correlation coefficients among the excess cash, stock, and option liquidity in this paper. Similar to the observations in Cao and Wei (2010), the option liquidity measures are highly correlated. The correlation coefficients of option trading volume to the option proportional bid-ask spread and option interest are -0.80 and 0.98 respectively. Thus, option trading volume increases when the bid-ask spread declines, or the open interest rises. The correlation coefficient between the option proportional spread and the underlying stock bid-ask spread is 0.21. We observe a positive relation between excess cash and option market liquidity. That is, excess cash is positively correlated with option trading volume, open interest, and is negatively related to option proportional spread. These relationships are all significant at one percent level. Thus, companies with greater excess cash tend to observe a higher degree of option market liquidity.

	ECASH	OBAS	OI	OVOL	SBAS
ECASH	1				
OBAS	-0.13 ***	1			
OI	0.18 ***	-0.80 ***	1		
OVOL	0.19 ***	-0.80 ***	0.98 ***	1	
SBAS	-0.06 ***	0.21 ***	-0.27 ***	-0.27 ***	1

Notes: This table shows the pair-wise correlations of excess cash, stock market liquidity, and option liquidity measures from Jan 3, 2005 to Aug 31, 2015. These correlation coefficients and the *t*-statistics are computed for each firm and averaged across all firms over the sample. ECASH is the excess cash obtained from the residuals in the equation (1). Option liquidity measures include option proportional bid-ask spread (OBAS), the natural log of yearly total option volume (OVOL), the natural log of yearly total open interest (OI). SBAS is the stock proportional bid-ask spread. The values of ECASH and SBAS are lagged in one year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 5.3 Correlation Matrix of Excess Cash, Stock and Option Liquidity

Figure 5.1 illustrates the relationship between excess cash and option market liquidity. We compute the average annual excess cash for each firm from Jan 3, 2005 to Aug 31, 2015. We then classify firms into ten equal number groups and sort them increasingly from the Group 1 (bottom group) to Group 10 (top group) based on the level of excess cash. We also compute the average of the option proportional spread (OBAS) for each group. The figure shows a clear relation between excess cash and option proportional spread. We observe that option liquidity increases, that is, the proportional bid-ask spread declines when the level of excess cash increases[28]. These results are consistent with Gopalan *et al*. (2012)' predictions that market liquidity increases in excess cash.

[28] The relation between excess cash and other liquidity measures such as option interest and trading volume is qualitatively similar. We observe that option interest and trading volume increase when the level of excess cash increases.

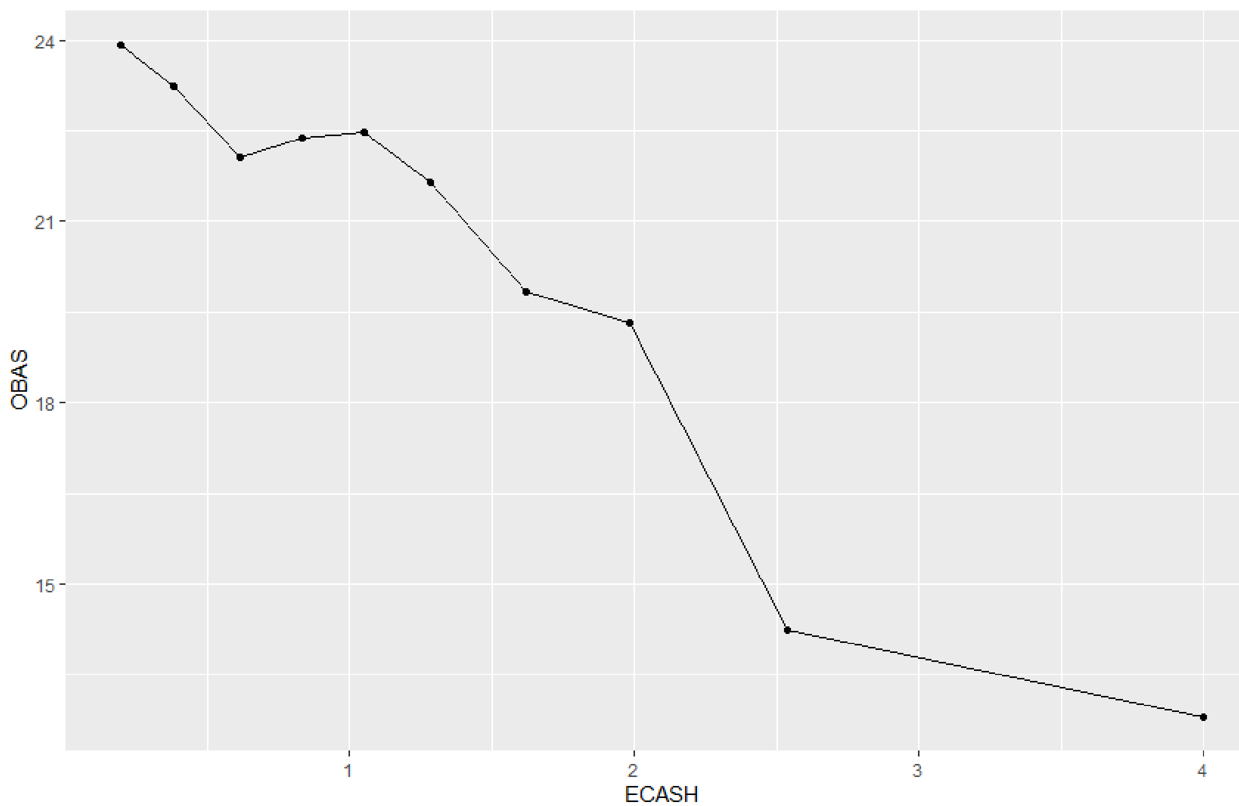


Figure 5.1 Excess Cash and Option Bid-Ask Spread

Notes: This figure shows the relationship between excess cash (ECASH) and option proportional bid-ask spread (OBAS) (in percentage points). Excess cash is the exponential form of residual obtained from the regression equation (1). We compute the average annual excess cash for each firm from Jan 3, 2005 to Aug 31, 2015. We then sort firms into ten equal number groups increasingly from Group 1 (bottom group) to Group 10 (top group) based on the level of excess cash. The option proportional bid-ask spread (in percentage points) is equally weighted averaged for each group.

5.4.2 Excess Cash and Option Liquidity

Table 5.4 reports the results from regression model (2) and demonstrates the role of excess cash holding in affecting option market liquidity [29]. Column (1) shows the coefficients and *t*-statistics (in parentheses) from the regressions where option proportional bid-ask spread serves as the dependent variable. Consistent with the argument in Gopalan *et al*. (2012), firms with higher excess cash experience higher option market liquidity. Excess cash is significantly and negatively related to option bid-ask spread. An increase of 1% in excess cash holding leads to a 0.58% reduction in option bid-ask spread and the relation is significant at one percent level. In

[29] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 1.69, indicating that our results are not significantly affected by multicollinearity problems.

addition, we observe that stock bid-ask spread explains option bid-ask spread. Thus, higher liquidity in the underlying stock leads to an increase in option market liquidity, a pattern consistent with derivatives hedging theory put forth in Cho and Engle (1999).

Column (2) and Column (3) display the results where option open interest and option trading volume serve as alternative measures of option liquidity in addition to option bid-ask spread. The results show that excess cash is positively related to option open interest and trading volume. The regression R-square is about 0.52, suggesting that a large variation in option market liquidity can be explained by the model.

Our results support the argument that excess cash affects option market liquidity. Excess cash matters because it reflects a firm's growth options (See Simutin, 2010), or signals the ability to invest more and produce higher profits (See Mikkelson and Partch, 2003) and because excess cash protects firms from adverse shortfalls in future cash flows (See Bates *et al.*, 2009). According to Gopalan *et al*. (2012), excess cash improves market liquidity due to reductions in adverse selection problems associated with the uncertainty in firm's asset values. Providing the evidence consistent with Gopalan *et al*. (2012)'s predictions, our paper is the first to show that option market liquidity is not only affected by other exogenous sources but also is explained by the variations in excess cash across firms.

	OBAS	OI	OVOL
	(1)	(2)	(3)
ECASH	-0.58 (-3.05) ***	0.28 (2.92) ***	0.26 (3.13) ***
MTB	-1.20 (-9.76) ***	0.49 (12.37) ***	0.47 (13.33) ***
SIZE	-2.22 (-23.83) ***	1.12 (27.25) ***	0.97 (26.12) ***
LEVER	0.62 (1.50)	-0.38 (-1.84) *	-0.35 (-2.00) **
DIV	1.78 (10.16) ***	-1.12 (-14.13) ***	-1.03 (-14.61) ***
CAPEX	-0.21 (-9.07) ***	0.11 (10.19) ***	0.10 (10.17) ***
RND	-2.10 (-4.60) ***	1.31 (4.52) ***	1.12 (4.28) ***
PRICE	-1.37 (-5.87) ***	-0.06 (-0.56)	0.15 (1.62)
RET	-0.16 (-6.07) ***	0.09 (8.13) ***	0.09 (8.31) ***
NSHAR	0.10 (2.41) **	-0.03 (-1.53)	-0.04 (-2.26) ***
SBAS	0.18 (9.19) ***	-0.09 (-9.75) ***	-0.08 (-10.05) ***
Constant	1.23 (0.89)	2.71 (7.45) ***	1.84 (5.62) ***
Observations	5026	5026	5026
RSQ	0.50	0.52	0.52
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: This table shows the coefficients and the *t*-statistics (in parentheses) of the regressions estimated over the sample period from Jan 3, 2005 to Aug 31, 2015. The dependent variables include three option illiquidity measures: (1) 10 times the log of option proportional bid-ask spread (OBAS); (2) the natural log of total option volume (OVOL); (3) the natural log of open interest (OI). LEVER is the ratio of total debt to net assets; MTB is the market value of assets divided by total assets; SIZE is the natural log of net assets deflated in 1994 dollars; CAPEX is 100 times capital expenditures scaled by net assets; DIV is a dummy variable which equals one if the firm pays dividends and zero otherwise; RND is the research and development expenditures scaled by sales; PRICE is the stock price divided by 100; RET is 100 times the stock return; NSHAR is the number of shareholders, SBAS is the stock proportional bid-ask spread (in basis points). Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables used to control for year and industry fixed effects, respectively. RSQ is the regression R-Squared. The *t*-statistics are adjusted for clustering by firm and year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 5.4 Explaining Option Market Liquidity

5.4.3. Excess Cash and Information Asymmetry

Having established the relation between excess cash and option market liquidity, we examine the joint effects of information asymmetry and excess cash in explaining option market liquidity. To reflect the information asymmetry problem, we use a dummy variable, PINDUM, which equals 1 for firms with a probability of informed trading (*PIN*) greater than the annual cross-sectional median and zero, otherwise. We focus on the joint interaction between excess cash and information asymmetry and expect that information asymmetry will reinforce the role of excess cash on option market liquidity.

Table 5.5 present the results of the regressions (equation 3) including the probability of informed trading [30]. Column 1 shows the results where option proportional bid-ask spread serves as the dependent variable. The coefficient of excess cash remains negative and significant as seen in Table 5.4. The coefficient of the interaction term between the probability of informed trading and excess cash is negative and significant. This result suggests that among groups of firms with a higher probability of informed trading, excess cash matters even more and determines option market liquidity. Consistent with the predictions by Lin *et al*. (2009) and Gopalan *et al*. (2012), this finding suggests that excess cash helps reduce firm valuation uncertainty, and therefore, excess cash affects option market liquidity, especially in firms with a higher degree of information-driven trading. Similar results are also observed in Column (2) and Column (3) of Table 5 where option open interest and trading volume are used as the option liquidity measures. The coefficients of the interaction terms between the probability of informed trading and excess cash are all positive and significant. The evidence indicates that option market liquidity is higher in firms with a higher level of excess cash holding, especially for firms with a higher level of probability of informed trading.

[30] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 2.04, indicating that our results are not significantly affected by multicollinearity problems.

	OBAS	OI	OVOL
	(1)	(2)	(3)
ECASH × PINDUM	-0.27 (-1.72) *	0.24 (3.37) ***	0.19 (2.81) ***
ECASH	-0.47 (-3.54) ***	0.21 (3.78) ***	0.20 (3.66) ***
PINDUM	3.35 (7.53) ***	-1.65 (-9.25) ***	-1.48 (-8.74) ***
MTB	-1.74 (-6.81) ***	0.58 (7.26) ***	0.56 (7.74) ***
SIZE	-1.41 (-10.95) ***	0.79 (14.02) ***	0.67 (13.14) ***
LEVER	-0.46 (-1.26)	0.28 (1.65) *	0.19 (1.21)
DIV	2.08 (8.57) ***	-1.06 (-9.93) ***	-0.91 (-9.56) ***
CAPEX	-0.18 (-6.33) ***	0.08 (6.87) ***	0.07 (7.03) ***
RND	-1.10 (-3.44) ***	0.66 (3.49) ***	0.53 (3.13) ***
PRICE	-4.53 (-7.86) ***	0.59 (3.28) ***	0.90 (5.22) ***
RET	-0.12 (-3.91) ***	0.07 (5.28) ***	0.07 (5.57) ***
NSHAR	0.13 (2.20) **	-0.03 (-1.14)	-0.05 (-2.05) **
SBAS	0.13 (6.94) ***	-0.07 (-7.76) ***	-0.07 (-7.71) ***
Constant	-7.06 (-3.76) ***	7.27 (14.79) ***	5.95 (13.48) ***
Observations	2013	2013	2013
RSQ	0.54	0.57	0.56
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: This table shows the coefficients and the *t*-statistics (in parentheses) of the regressions estimated over the sample period from Jan 3, 2005 to Aug 31, 2015. There are three option liquidity measures: (1) 10 times the log of option proportional bid-ask spread (OBAS); (2) the natural log of yearly total option volume (OVOL); (3) the natural log of yearly total open interest (OI). PINDUM equals 1 for firms with a probability of informed trading (PIN) greater than the yearly cross-sectional median and zero, otherwise; LEVER is the ratio of total debt to net assets; MTB is the market value of assets divided by total assets; SIZE is the natural log of net assets deflated in 1994 dollars; CAPEX is 100 times capital expenditures scaled by net assets; DIV is a dummy variable which equals one if the firm pays dividends and zero otherwise; RND is the research and development expenditures scaled by sales; PRICE is the stock price divided by 100; RET is 100 times the stock return; NSHAR is the number of shareholders, SBAS is the stock proportional bid-ask spread. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables used to control for year and industry fixed effects, respectively. RSQ is the regression R-Squared. The *t*-statistics are adjusted for clustering by firm and year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 5.5 Information Asymmetry and Excess Cash in Determining Option Market Liquidity

Table 5.6 shows the results for model (5) that includes insider trading [31]. Similar to the above results with the probability of informed trading, the coefficient for the interaction term between excess cash is negative when option bid-ask spread is the dependent variable, and they are positive when option interest and volume serve as the liquidity measures. Consistent with the

[31] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 4.78, indicating that our results are not significantly affected by multicollinearity problems.

predictions by Lin *et al*. (2009) and Gopalan *et al*. (2012), this result suggests that the relation between excess cash and option market liquidity becomes stronger in firms subject to a higher degree of insider trading. The findings indicate that when facing a higher degree of information asymmetry or a higher level of corporate insider trading, investors increasingly value higher excess cash due to the reductions in firm valuation uncertainty.

In addition to the interaction terms, we observe a positive and significant impact of the probability of informed trading (in Table 7.5) or insider trading (in Table 7.6) on option bid-ask spread or negative coefficients with option interest and option trading volume. This is consistent with the theories in the literature (e.g., Kyle, 1985) that market liquidity declines in the degree of information asymmetry or insider trading. Market makers are assumed not to have any private information and are unable to know the actual intentions of the traders. Because they tend to incur losses when trading with informed traders, market makers need to set a bid-ask spread wide enough to compensate them for the informational disadvantages.

	OBAS	OI	OVOL
	(1)	(2)	(3)
ECASH×INSIDER	-0.07 (-1.96) **	0.05 (2.20) **	0.05 (2.65) ***
ECASH	-1.21 (-2.30) ***	0.65 (2.84) ***	0.53 (2.57) ***
INSIDER	0.11 (3.83) ***	-0.08 (-4.94) ***	-0.08 (-5.07) ***
MTB	-0.17 (-1.62)	0.03 (0.74)	0.07 (2.14) **
SIZE	-3.40 (-24.06) ***	1.65 (27.14) ***	1.45 (26.72) ***
LEVER	0.58 (0.83)	-0.53 (-1.84) *	-0.54 (-2.04) **
DIV	1.27 (4.69) ***	-0.74 (-6.25) ***	-0.72 (-6.74) ***
CAPEX	-0.32 (-7.71) ***	0.15 (8.84) ***	0.15 (9.47) ***
R&D	-25.39 (-11.24) ***	13.97 (15.86) ***	12.59 (15.47) ***
PRICE	-0.84 (-3.92) ***	-0.06 (-0.57)	0.11 (1.05)
RET	-0.15 (-2.96) ***	0.07 (3.14) ***	0.07 (3.34) ***
NSHAR	0.08 (1.22)	0.00 (0.05)	-0.02 (-0.70)
SBAS	0.15 (4.29) ***	-0.05 (-3.75) ***	-0.05 (-3.70) ***
Constant	10.63 (7.17) ***	-3.07 (-5.20) ***	-3.38 (-6.41) ***
Observations	2380	2380	2380
RSQ	0.58	0.64	0.63
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: This table shows the coefficients and the *t*-statistics (in parentheses) of the regressions estimated over the sample period from Jan 1, 2009 to Aug 31, 2015. There are three option liquidity measures: (1) 10 times the log of option proportional bid-ask spread (OBAS); (2) the natural log of yearly total option volume (OVOL); (3) the natural log of yearly total open interest (OI). INSIDER is the Insider ownership, which refers as the ratio of the total number of shares traded by insiders to the total number of shares outstanding; ECASH is the excess cash; LEVER is the ratio of total debt to net assets; MTB is the market value of assets divided by total assets; SIZE is the natural log of net assets deflated in 1994 dollars; CAPEX is 100 times capital expenditures scaled by net assets; DIV is a dummy variable which equals one if the firm pays dividends and zero otherwise; R&D is the research and development expenditures scaled by sales; PRICE is the stock price divided by 100; RET is 100 times the stock return; NSHAR is the number of shareholders, SBAS is the stock proportional bid-ask spread. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables used to control for year and industry fixed effects, respectively. RSQ is the regression R-Squared. The *t*-statistics are adjusted for clustering by firm and year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 5.6 Insider Trading and Excess Cash in Explaining Option Market Liquidity

5.4.4 Controlling for Investor Sentiment

Previous studies (e.g., Verousis *et al*., 2016b) show that investor sentiment affects option liquidity. In this study, we investigate the role of investor sentiment in the relation between excess cash and option market liquidity. According to the literature (See, for instance, Wang, 2001), investor sentiment matters as overconfidence and bullish sentiment might dominate concerns about fundamental risk and the uncertainty of firm future cash flows, and therefore, reducing the influences of excess cash on market liquidity. Following Verousis *et al*. (2016b) we use the ratio of put-to-call traded volume to capture investor sentiment. A rise (fall) in the ratio means that more put options being bought relative to call options. An increase in the ratio indicates that investors become bearish and are more likely to expect falling asset prices. Lower values of the ratio suggest that investors become bullish and tend to expect rising asset prices. For these reasons, the following hypothesis will be tested:

H_5: Excess cash further increases option liquidity when option traders become more bullish.

Table 5.7 shows the results of the regressions including the interaction between investor sentiment and excess cash[32]. We use a dummy variable, SENDUM which equals 1 for firms with investor sentiment greater than the cross-sectional average for the whole period and zero, otherwise. The coefficient of the interaction term between excess cash and investor sentiment shows the effects of investor sentiment on the relation between excess cash and option liquidity.

We observe that investor sentiment affects option liquidity. The coefficient of investor sentiment is positive for bid-ask spread while their coefficients with option interest and volume are negative. Thus, it means that option liquidity declines when more put options are traded relative to call options. Our results support the argument of Verousis *et al*. (2016b), that bearish investor sentiment reduces option liquidity while bullish sentiment reinforces market liquidity.

We observe that the coefficient for the interaction term between investor sentiment and excess cash is negative for option bid-ask spread and is positive for open interest and trading volume. The coefficients are all significant and indicate that excess cash has a stronger impact on option market liquidity when investors become more bearish. The results support the arguments (See, for instance, Wang, 2001) that when bearish sentiment dominates, investors become more concerned about fundamental risk and about uncertainty about asset values, therefore, leading to a more pronounced effect of excess cash on market liquidity. The findings reinforce the importance of excess cash and demonstrate a stronger relation between excess cash and option market liquidity at times of bearish investor sentiments.

[32] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 1.82, indicating that our results are not significantly affected by multicollinearity problems.

	OBAS	OI	OVOL
	(1)	(2)	(3)
ECASH×SENDUM	-0.37 (-1.68) *	0.22 (2.19) **	0.18 (1.98) **
ECASH	-0.41 (-1.87) *	0.17 (1.72) *	0.17 (1.92) *
SENDUM	2.10 (5.38) ***	-1.34 (-7.41) ***	-1.12 (-6.96) ***
MTB	-1.08 (-8.81) ***	0.42 (10.88) ***	0.41 (11.80) ***
SIZE	-2.17 (-23.13) ***	1.08 (26.20) ***	0.94 (25.05) ***
LEVER	0.75 (2.03) **	-0.46 (-2.55) **	-0.42 (-2.69) ***
DIV	1.65 (9.77) ***	-1.04 (-13.68) ***	-0.96 (-14.22) ***
CAPEX	-0.20 (-9.45) ***	0.10 (10.91) ***	0.09 (10.78) ***
RND	-1.93 (-4.43) ***	1.20 (4.33) ***	1.03 (4.09) ***
PRICE	-1.60 (-6.52) ***	0.10 (0.98)	0.28 (3.01) ***
RET	-0.13 (-5.27) ***	0.07 (7.00) ***	0.07 (7.26) ***
NSHAR	0.10 (2.37) **	-0.03 (-1.46)	-0.04 (-2.21) **
SBAS	0.18 (9.99) ***	-0.09 (-10.95) ***	-0.09 (-10.99) ***
Constant	0.25 (0.18)	3.35 (8.74) ***	2.39 (6.86) ***
Observations	5026	5026	5026
RSQ	0.51	0.55	0.55
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: This table shows the coefficients and the *t*-statistics (in parentheses) of the regressions estimated over the sample period from Jan 3, 2005 to Aug 31, 2015. There are three option liquidity measures: (1) 10 times the log of option proportional bid-ask spread (OBAS); (2) the natural log of yearly total option volume (OVOL); (3) the natural log of yearly total open interest (OI). Sentiment refers to the put-to-call ratio of daily option traded volume across all firms per year; SENDUM equals 1 for firms with investor sentiment (Sentiment) greater than the yearly cross-sectional median and zero, otherwise; LEVER is the ratio of total debt to net assets; MTB is the market value of assets divided by total assets; SIZE is the natural log of net assets deflated in 1994 dollars; CAPEX is 100 times capital expenditures scaled by net assets; DIV is a dummy variable which equals one if the firm pays dividends and zero otherwise; RND is the research and development expenditures scaled by sales; PRICE is the stock price divided by 100; RET is 100 times the stock return; NSHAR is the number of shareholders, SBAS is the stock proportional bid-ask spread on a basis point. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables used to control for year and industry fixed effects, respectively. RSQ is the regression R-Squared. The *t*-statistics are adjusted for clustering by firm and year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 5.7 Investor Sentiment and Excess Cash in Explaining Option Market Liquidity

5.4.5 Impacts During Periods of High Volatility

In addition to information asymmetry and investor sentiment, we study how the effects of excess cash on option market liquidity vary when market volatility changes. There are two potential competing effects of volatility on market liquidity. On the one hand, we expect that excess cash will have stronger effects on market liquidity when volatility increases. This is because market participants including investors and market makers become more attracted by cash-rich firms due to the reductions in adverse selection costs and by greater valuation certainty in firm assets. In particular, following the theories developed in Stoll (1978), Grossman and Miller (1988), and Gromb and Vayanos (2002), maker makers will focus more efforts on cash-rich firms to preserve expensive dealer capital, which consequently leads to episodes often described as “flight-to-liquidity” and “flight-to-quality” events in financial markets. For these reasons, the following hypothesis will be tested:

H_6: Excess cash further increases option liquidity in volatile markets.

On the other hand, the previous literature (e.g., Ross, 1989) suggests that higher volatility also encourages better information flow in financial markets, reduces the uncertainty about asset values, and therefore, potentially lowering the effects of excess cash on market liquidity.
For these reasons, the following hypothesis will be tested:

H_7: Excess cash reduces the effect of the increase in option liquidity in volatile markets.

To assess these competing effects of volatility, we adopt two measures of aggregate volatility. The first volatility measure is the macroeconomic uncertainty index[33]. According to Jurado *et al.* (2015), this uncertainty index is calculated as the conditional volatility of the purely unpredictable component across a large set of macroeconomic series. The economic uncertainty index typically rises during bad states of the economy (that is, ‘the periods of high unemployment, low output growth, and low economic activity’). As studied in the previous literature (See Jurado *et al.*, 2015; Kambouroudis and McMillan, 2016; Bali *et al.*, 2017), this measure reflects significant variations in business conditions which potentially lead to greater

[33] The data for the series for the period January 2005- August 2015 is obtained from Sydney Ludvigson’s website (https://www.sydneyludvigson.com/macro-and-financial-uncertainty-indexes).

uncertainty in firm valuations. The second measure of market volatility is the VIX index obtained from the Chicago Board Options Exchange. The VIX index captures the volatility extracted from the S&P500 option prices. The index is widely used in the literature to provide a forward-looking measure of financial market volatility (See, Whaley, 2009). We expect that excess cash will have a stronger effect on market liquidity during periods of high uncertainty in financial markets and the economy. In our paper, we define a dummy variable, *VOLDUM*, which equals 1 when the volatility index (or the macroeconomic uncertainty index) is higher than their mean value, and zero otherwise. We include this dummy variable in regression model (2) and estimate the regression over the whole sample period as:

$$OPTLIQ_{i,t} = \kappa_0 + \kappa_1 * ECASH_{i,t-1} * VOLDUM + \kappa_2 * ECASH_{i,t-1} + \kappa_3 * VOLDUM + \gamma_0 * X_{i,t-1} + \gamma_1 * X_{i,t-1} * VOLDUM + YEAR + INDUSTRY + \nu_{i,t} \quad (7)$$

Table 5.8 shows the effects of excess cash on market liquidity when uncertainty changes [34]. Panel A shows the result when the macroeconomic uncertainty index is used as the volatility index. We observe that excess cash remains important for option market liquidity. Importantly, the coefficients of excess cash are significantly higher when market volatility increases. For instance, in Column 1, the coefficient of excess cash on option bid-ask spread nearly doubles (i.e., the coefficient increases by -0.14 from -0.05) when the uncertainty index is higher than average. Excess cash also registers significantly higher coefficients when option interest and trading volume are used as the liquidity measure.

A similar pattern is observed when the financial market volatility, the VIX index, serves as a proxy for aggregate volatility (Panel B of Table 7.8)[35]. The coefficient of excess cash on option bid-ask spread remains negative and becomes significantly higher when financial market volatility increases (Column 1). These results support the "flight-to-quality" and "flight-to-liquidity" argument (e.g., Gromb and Vayanos, 2002). At times of high uncertainty, investors increasingly congregate to firms with higher excess cash due to the reductions in adverse selection problems associated with excess cash (Gopalan *et al*., 2012). These effects lead to a

[34] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 10.67, indicating that our results are significantly affected by multicollinearity problems.
[35] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 10.04, indicating that our results are significantly affected by multicollinearity problems.

stronger relation between excess and option market liquidity during periods of high financial and macroeconomic uncertainty.

Panel A: High Macro-Economic Uncertainty Period

	OBAS (1)	OI (2)	OVOL (3)
ECASH	-0.05 (-2.33) **	0.28 (2.32) **	0.25 (2.33) **
ECASH×VOLDUM	-0.14 (-3.40) ***	0.69 (3.33) ***	0.62 (3.32) ***
MTB	-0.86 (-11.81) ***	5.29 (12.05) ***	4.57 (12.10) ***
SIZE	-0.09 (-3.80) ***	0.57 (4.06) ***	0.48 (3.96) ***
LEVER	0.34 (6.43) ***	-2.31 (-7.19) ***	-1.95 (-7.08) ***
DIV	-0.01 (-0.43)	0.07 (0.50)	0.03 (0.24)
CAPEX	-1.49 (-3.90) ***	8.61 (4.13) ***	7.64 (4.14) ***
R&D	-0.13 (-2.22) **	0.75 (2.08) **	0.65 (2.10) **
PRICE	-0.07 (-1.57)	0.35 (1.42)	0.39 (1.70) *
RET	-0.75 (-2.03) **	5.21 (2.33) **	4.55 (2.32) **
NSHAR	-0.01 (-2.56) **	0.08 (3.04) ***	0.07 (2.86) ***
SBAS	0.08 (0.40)	-0.29 (-0.23)	-0.12 (-0.11)
MTB×VOLDUM	-0.33 (-1.70) *	1.76 (1.56)	1.48 (1.54)
SIZE×VOLDUM	-0.03 (-0.53)	0.09 (0.33)	0.10 (0.41)
LEVER×VOLDUM	0.35 (2.45) **	-1.58 (-2.08) **	-1.44 (-2.14) **
DIV×VOLDUM	0.25 (2.55) **	-1.17 (-2.50) **	-1.06 (-2.44) **
CAPEX×VOLDUM	-0.51 (-0.83)	2.07 (0.64)	1.71 (0.59)
R&D×VOLDUM	-0.09 (-1.12)	0.45 (0.96)	0.40 (0.98)
PRICE×VOLDUM	-0.63 (-1.48)	2.70 (1.40)	2.57 (1.40)
RET×VOLDUM	0.01 (0.02)	-0.53 (-0.14)	-0.30 (-0.09)
NSHAR×VOLDUM	-0.02 (-2.05) **	0.11 (1.81) *	0.10 (1.87) *
SBAS×VOLDUM	-0.12 (-0.23)	-0.78 (-0.29)	-0.50 (-0.20)
VOLDUM	0.38 (1.08)	-1.37 (-0.69)	-1.34 (-0.77)
Constant	1.52 (5.00) ***	-10.05 (-6.29) ***	-8.77 (-6.43) ***
Observations	5026	5026	5026
RSQ	0.57	0.61	0.60
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel B: High Financial Market Volatility Period

	OBAS (1)	OI (2)	OVOL (3)
ECASH	-0.07 (-2.63) **	0.40 (2.65) ***	0.35 (2.64) ***
ECASH×VIXDUM	-0.11 (-1.83) *	0.53 (1.83) *	0.48 (1.80) *
MTB	-0.89 (-12.68) ***	5.45 (13.03) ***	4.70 (13.08) ***
SIZE	-0.11 (-4.72) ***	0.66 (4.97) ***	0.56 (4.89) ***
LEVER	0.41 (7.31) ***	-2.59 (-7.99) ***	-2.22 (-7.84) ***
DIV	0.04 (1.21)	-0.19 (-1.05)	-0.21 (-1.25)
CAPEX	-1.62 (-4.37) ***	9.12 (4.53) ***	8.06 (4.54) ***
R&D	-0.15 (-3.37) ***	0.86 (3.12) ***	0.75 (3.16) ***
PRICE	-0.14 (-1.77) *	0.63 (1.71) *	0.66 (1.89) *
RET	-0.81 (-1.99) **	4.51 (2.15) **	4.22 (2.21) **
NSHAR	-0.02 (-3.73) ***	0.12 (4.17) ***	0.10 (4.00) ***
SBAS	0.25 (1.02)	-1.53 (-1.17)	-1.14 (-0.98)
MTB× VIXDUM	-0.33 (-0.96)	1.89 (0.92)	1.64 (0.93)
SIZE×VIXDUM	-0.02 (-0.22)	0.05 (0.11)	0.05 (0.11)
LEVER×VIXDUM	0.69 (2.19) **	-3.35 (-2.17) **	-2.97 (-2.17) **
DIV×VIXDUM	0.19 (1.31)	-0.84 (-1.27)	-0.75 (-1.22)
CAPEX× VIXDUM	-0.97 (-0.99)	4.59 (0.92)	3.94 (0.90)
R&D× VIXDUM	-0.09 (-1.03)	0.45 (0.92)	0.40 (0.95)
PRICE× VIXDUM	-0.45 (-0.68)	1.79 (0.63)	1.77 (0.66)
RET× VIXDUM	-0.07 (-0.05)	4.32 (0.64)	2.74 (0.44)
NSHAR× VIXDUM	-0.02 (-1.12)	0.10 (0.96)	0.09 (0.98)
SBAS× VIXDUM	0.03 (0.04)	-0.61 (-0.16)	-0.61 (-0.18)
VIXDUM	0.29 (0.48)	-0.93 (-0.27)	-0.86 (-0.29)
Constant	1.68 (5.77) ***	-10.75 (-7.13) ***	-9.45 (-7.17) ***
Observations	5026	5026	5026
RSQ	0.55	0.60	0.59
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: This table shows the coefficients and the t-statistics (in parentheses) of the regressions estimated over the sample period from Jan 3, 2005 to Aug 31, 2015. Definitions of all variables are reported in Table 1 and Appendix. The estimations contain year and industry dummy variables. VIXDUM equals 1 when the financial market volatility is higher than the mean and zero, otherwise. VOLDUM equals 1 when the macro uncertainty index developed by Jurado, Ludvigson, and Ng (2015) is higher than the mean and zero otherwise. PRICE is the stock price divided by 100; SBAS is 100 times stock proportional spread. The t-statistics are adjusted for clustering by firm and year. Observations are the number of firm-year observations. RSQ is the regression R-Squared. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 5.8 Excess Cash and Market Liquidity During Periods of High Volatility

5.4.6 The Importance of Excess Cash During the Financial Crisis

We turn our attention to the time variations of the relation between option market liquidity and excess cash. We particularly focus on the dynamics between these variables during the financial crisis. Previous research (See Duchin *et al.*, 2010) shows that cash-rich firms perform better than cash-poor firms in the crisis, and stock market liquidity of these cash-rich firms improves as investors are attracted by their financial stability during market downturns. In addition, finance theories (See Gromb and Vayanos 2002) indicate that during these periods, financiers tend to increase margins for firms with higher valuation uncertainty, thus traders are more likely to avoid firms with lower excess cash. Thus, we expect that excess cash will have more significant impacts on option market liquidity at times of crisis. For these reasons, the following hypothesis will be tested:

H_8: Excess cash further increases option liquidity during the financial crisis.

Following the previous literature (e.g., Duchin *et al.*, 2010), we use a dummy variable, *CRIDUM*, which takes the value of 1 for the years of 2008 and 2009 and zero, otherwise. We include the dummy variable in the regression model (2) and estimate the regression over the whole sample period as follows:

$$OPTLIQ_{i,t} = \kappa_0 + \kappa_1 * ECASH_{i,t-1} * CRIDUM + \kappa_2 * ECASH_{i,t-1} + \kappa_3 * CRIDUM + \gamma_0 * X_{i,t-1} + \gamma_1 * X_{i,t-1} * CRIDUM + YEAR + INDUSTRY + \nu_{i,t} \quad (6)$$

Table 5.9 shows that excess cash has stronger impacts on option liquidity during the crisis[36]. Column (1) displays the results with option proportional bid-ask spread as the dependent variables. We observe that the impacts of excess cash on option bid-ask spread nearly double (that is, the coefficient increases by -0.14 during the financial crisis from -0.06 before and after the crisis). This result indicates more pronounced impacts of excess cash on the bid-ask spread during the financial crisis. Similar patterns are also observed with other option liquidity measures including option interests and trading volume. Columns (2) and (3) display the positive and significant coefficients of excess cash on option market liquidity during the crisis. Consistent

[36] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 10.49, indicating that our results are significantly affected by multicollinearity problems.

with the theories put forth by Gopalan *et al*. (2012), excess cash reduces adverse selection problems and affects option market liquidity, particularly during the financial crisis.

	OBAS (1)	OI (2)	OVOL (3)
ECASH	-0.06 (-2.52) **	0.36 (2.53) **	0.31 (2.54) **
ECASH×CRIDUM	-0.14 (-2.67) ***	0.68 (2.65) ***	0.62 (2.62) ***
MTB	-0.87 (-12.31) ***	5.36 (12.66) ***	4.62 (12.71) ***
SIZE	-0.10 (-4.30) ***	0.61 (4.55) ***	0.52 (4.47) ***
LEVER	0.34 (7.16) ***	-2.26 (-7.67) ***	-1.92 (-7.61) ***
DIV	0.02 (0.70)	-0.09 (-0.56)	-0.11 (-0.80)
CAPEX	-1.42 (-3.98) ***	8.24 (4.22) ***	7.27 (4.22) ***
R&D	-0.13 (-3.13) ***	0.75 (2.91) ***	0.65 (2.95) ***
PRICE	-0.08 (-1.63)	0.34 (1.37)	0.39 (1.68) *
RET	-1.25 (-2.96) ***	7.46 (3.25) ***	6.61 (3.22) ***
NSHAR	-0.02 (-3.33) ***	0.10 (3.72) ***	0.09 (3.56) ***
SBAS	0.31 (1.47)	-1.74 (-1.40)	-1.38 (-1.27)
MTB×CRIDUM	-0.43 (-1.71) *	2.03 (1.37)	1.75 (1.38)
SIZE×CRIDUM	-0.03 (-0.53)	0.12 (0.34)	0.12 (0.39)
LEVER×CRIDUM	0.82 (3.46) ***	-4.08 (-3.45) ***	-3.63 (-3.43) ***
DIV×CRIDUM	0.23 (1.82) *	-0.98 (-1.70) *	-0.91 (-1.67) *
CAPEX×CRIDUM	-1.59 (-1.89) *	7.42 (1.72) *	6.56 (1.72) *
R&D×CRIDUM	-0.16 (-1.91) *	0.81 (1.79) *	0.71 (1.78) *
PRICE×CRIDUM	-0.96 (-1.32)	4.33 (1.30)	4.11 (1.30)
RET×CRIDUM	0.45 (0.50)	-2.68 (-0.59)	-2.17 (-0.52)
NSHAR×CRIDUM	-0.02 (-1.63)	0.11 (1.52)	0.10 (1.55)
SBAS×CRIDUM	-1.04 (-1.29)	4.34 (1.11)	4.06 (1.12)
CRIDUM	0.67 (1.39)	-2.92 (-1.10)	-2.67 (-1.15)
Constant	1.59 (5.18) ***	-10.36 (-6.49) ***	-9.06 (-6.59) ***
Observations	5026	5026	5026
RSQ	0.57	0.61	0.60
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: The table shows the coefficients and the *t*-statistics in brackets from regressions performed over the whole sample period. There are three option illiquidity measures: the log of option proportional bid-ask spread (OBAS); (2) the natural log of yearly total option volume (OVOL); (3) the natural log of yearly total open interest (OI). Definitions of all variables are reported in Table 1 and Appendix. CRIDUM equals 1 if the year is 2008 or 2009, and zero otherwise. PRICE is the stock price divided by 100; SBAS is 100 times stock proportional spread. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables used to control for year and industry fixed effects, respectively. RSQ is the regression R-Squared. The *t*-statistics, which are adjusted for clustering by firm and year, are reported in parentheses. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 5.9 The Role of Excess Cash During the Financial Crisis

5.5 Robustness Checks

We first present the results from the regressions that control for the agency conflicts. We then consider the sensitivities of our results with different weighting average schemes for option bid-ask spread and finally study the joint influences of excess cash and option market liquidity.

5.5.1 Controlling for Agency Conflicts

Theories developed in Ball *et al*. (2000) and Ball (2006) indicate that companies with higher excess cash might experience a high level of agency conflicts, and therefore, market liquidity should decline in excess cash. In this study, we use the degree of board independence to capture the level of agency conflicts of firms. The previous literature (See, for instance, Hermalin and Weisbach, 2003) suggests that board composition can influence managerial incentives, and consequently, it affects the dynamic of the agency conflicts between managers and shareholders. In particular, the presence of outside directors contributes to improvements in monitoring and disciplining insider managers. The existence of outside (non-executive) directors does not only improve the alignment in the interest between managers and shareholders (See Rosenstein and Wyatt, 1997; Mayers *et al*., 1997) but also facilitates more efficient decision making than that of firms with insider-dominated boards (See Borokhovich *et al.*, 1996), and therefore, higher board independence helps reduce agency conflicts. For these reasons, the following hypothesis will be tested:

H_9: Excess cash further increases option liquidity in the firms with higher board independence.

Following Ozkan and Ozkan (2004), we use NONEX, the natural logarithm ratio of non-executive directors to the total number of board directors to capture the board independence. A higher ratio indicates the firms with greater outside (non-executive) director representation and more board independence while a lower ratio represents the firms dominated by inside (executive) directors. We obtain details about the directors from the ISS Director data over the period between Jan 1, 2009 to Aug 31, 2015.

Table 5.10 illustrates the results of regressions that control for the effects of board independence [37]. The coefficients of the board independence are negative for option bid-ask spread and positive for option volume and interest. The results are consistent with the literature (See Rosenstein and Wyatt, 1997; Mayers *et al*., 1997, Borokhovich *et al*., 1996) that higher board independence reduces agency conflicts, reinforces more efficient decision making, and hence, market liquidity increases in board independence. Considering the interaction term between board independence and excess cash, we observe that option market liquidity rises when excess cash and board independence increase. Thus, excess cash affects market liquidity even after controlling for the effects of board independence and agency conflicts.

[37] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 2.53, indicating that our results are not significantly affected by multicollinearity problems.

	OBAS (1)	OI (2)	OVOL (3)
ECASH×NONEX	-1.56 (-2.42) **	0.58 (2.24) **	0.50 (2.22) **
ECASH	-1.46 (-8.88) ***	0.58 (8.31) ***	0.53 (8.52) ***
NONEX	-2.61 (-1.81) *	1.13 (2.04) **	1.16 (2.38) **
MTB	-0.08 (-0.77)	-0.03 (-0.78)	0.02 (0.70)
SIZE	-3.58 (-26.65) ***	1.76 (31.41) ***	1.54 (30.61) ***
LEVER	1.29 (1.89) *	-0.91 (-3.15) ***	-0.90 (-3.43) ***
DIV	1.27 (4.92) ***	-0.78 (-6.86) ***	-0.74 (-7.32) ***
CAPEX	-0.30 (-7.66) ***	0.14 (8.30) ***	0.14 (8.98) ***
R&D	-25.92 (-11.87) ***	14.14 (16.46) ***	12.74 (16.28) ***
PRICE	-0.80 (-3.74) ***	-0.07 (-0.64)	0.10 (0.96)
RET	-0.15 (-3.30) ***	0.08 (3.96) ***	0.08 (4.24) ***
NSHAR	0.07 (1.03)	0.01 (0.21)	-0.01 (-0.55)
SBAS	0.14 (3.95) ***	-0.05 (-3.63) ***	-0.05 (-3.53) ***
Constant	8.76 (5.87) ***	-2.38 (-4.44) ***	-2.74 (-5.56) ***
Observations	2424	2424	2424
RSQ	0.60	0.65	0.65
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: This table shows the coefficients and the *t*-statistics (in parentheses) of the regressions estimated over the sample period from Jan 1, 2009 to Aug 31, 2015. There are three option liquidity measures: (1) 10 times the log of option proportional bid-ask spread (OBAS); (2) the natural log of yearly total option volume (OVOL); (3) the natural log of yearly total open interest (OI). NONEX refers to the natural logarithm ratio of independent directors to the total number of board directors. ECASH is the excess cash, LEVER is the ratio of total debt to net assets; MTB is the market value of assets divided by total assets; SIZE is the natural log of net assets deflated in 1994 dollars; CAPEX is 100 times capital expenditures scaled by net assets; DIV is a dummy variable which equals one if the firm pays dividends and zero otherwise; R&D is the research and development expenditures scaled by sales; PRICE is the stock price divided by 100; RET is 100 times the stock return; NSHAR is the number of shareholders, SBAS is the stock proportional bid-ask spread. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables used to control for year and industry fixed effects, respectively. RSQ is the regression R-Squared. The *t*-statistics are adjusted for clustering by firm and year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 5.10 Controlling for the Effects of Board Structure

5.5.2 Controlling for Different Weighting Average Schemes

As discussed in the data preparation in section 3, we use an equal weighting average scheme to obtain the option bid-ask spread for a stock across all individual option contracts of the same underlying. In this analysis, we assess the sensitivities of our results in different weighting average schemes for option bid-ask spread. We obtain the option volume-weighted average and the option interest-weighted average of the option bid-ask spread for common stocks on a daily basis. For brevity, we present the results of the regression model (2) with the option bid-ask spread obtained from these two weighting average schemes.

Table 5.11 illustrates the effects of excess cash on option bid-ask spread. Like the results in Table (4), we observe significant impacts of excess cash on option bid-ask spread [38]. Excess cash registers negative and significant coefficients to option bid-ask spread obtained from both weighting schemes. Consistent with the predictions in Gopalan *et al*. (2012), the findings indicate that excess cash significantly explains the variations in option market liquidity.

[38] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 1.69, indicating that our results are not significantly affected by multicollinearity problems.

	VWOBAS (1)	OIWOBAS (2)
ECASH	-0.18 (-3.26) ***	-0.21 (-2.90) ***
MTB	-0.50 (-15.31) ***	-0.42 (-12.37) ***
SIZE	-0.58 (-24.62) ***	-0.79 (-28.10) ***
LEVER	0.29 (2.56) ***	0.27 (1.83) *
DIV	0.55 (13.29) ***	0.68 (12.91) ***
CAPEX	-0.06 (-9.93) ***	-0.07 (-10.42) ***
R&D	-0.62 (-4.50) ***	-0.85 (-4.73) ***
PRICE	0.02 (0.47)	0.33 (5.65) ***
RET	-0.03 (-4.76) ***	-0.04 (-5.05) ***
NSHAR	0.01 (0.76)	0.003 (0.21)
SBAS	0.02 (5.32) ***	0.04 (6.82) ***
Constant	-0.28 (-1.24)	-1.24 (-4.30) ***
Observations	5026	5026
RSQ	0.57	0.56
Year FE	YES	YES
Industry FE	YES	YES

Note: This table shows the coefficients and the *t*-statistics (in parentheses) of the regressions estimated over the sample period from Jan 3, 2005 to Aug 31, 2015. The liquidity measures include two option spread measures: (1) the log of volume-weighted averaged option proportional bid-ask spread (VWOBAS); (2) the log of the open interest weighted averaged option proportional bid-ask spread (OIWOBAS). LEVER is the ratio of total debt to net assets; MTB is the market value of assets divided by total assets; SIZE is the natural log of net assets deflated in 1994 dollars; CAPEX is 100 times capital expenditures scaled by net assets; DIV is a dummy variable which equals one if the firm pays dividends and zero otherwise; R&D is the research and development expenditures scaled by sales; PRICE is the stock price divided by 100; RET is 100 times the stock return; NSHAR is the number of shareholders, SBAS is the stock proportional bid-ask spread (in basis points). Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables used to control for year and industry fixed effects, respectively. RSQ is the regression R-Squared. The *t*-statistics are adjusted for clustering by firm and year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 5.11 Assessing Different Weighting Average Schemes for Option Bid-ask Spread

5.5.3 Controlling for Endogeneity

This analysis considers the endogeneity problems in the relation between excess cash on option liquidity. According to Gopalan *et* al. (2012), there may be reverse causality running from market liquidity to excess cash. Because firms with less stock market liquidity typically encounter limited growth opportunities, they are less likely to convert liquid assets into uncertain investments, and hence, they tend to hold more cash. To control for this effect, we adopt an instrument variable (IV) approach and use the natural logarithm of the median of industry excess cash (IECASH) as the instrument for the individual firm cash flow. This variable is a valid instrument for firms' excess cash because firms in the same industry are more likely to adopt a similar cash holding policy. Meanwhile, individual liquidity characteristics are unlikely to have significant impacts on the industry cash holdings. Therefore, the industry excess cash holdings are more correlated with firm's excess cash while remaining uncorrelated with individual firm's option market liquidity[39].

In this analysis, we perform two-stage least squares (2SLS) regressions over the sample period. In the first stage, we regress the individual firm's excess cash on the industry excess cash and obtained the predicted values of the individual firm's excess cash. In the second stage, we regress option liquidity measures on the predicted firm excess cash and the set of control variables as detailed in table 4.

Table 5.12 shows the empirical results of these regressions. For brevity, we do not present the results for the first stage regression. However, we observe significant and positive relation between individual firm excess cash and industry cash holdings across all the firms. Columns (1), (2), and (3) show the results by regressing proportional spread, open interest, and trading volume respectively on the predicted excess cash holdings and the control variables. The coefficient for option proportional spread is negative and significant. This result indicates that higher excess cash holdings reduce option bid-ask spread. Results from columns (2) and (3) show that cash holdings positively explain option interest and trading volume. These findings show that excess cash significantly and positively affects option market liquidity.

[39] Following Davidson and MacKinnon (1993), we perform Durbin–Wu–Hausman test for endogeneity and results from the test show that industry excess cash is a suitable instrument for individual firm excess cash.

	OBAS (1)	OI (2)	OVOL (3)
ECASH*	-1.86 (-10.61) ***	1.06 (13.51) ***	0.96 (13.32) ***
MTB	-1.12 (-8.91) ***	0.45 (9.8) ***	0.43 (10.61) ***
SIZE	-2.39 (-16.79) ***	1.22 (16.34) ***	1.06 (15.98) ***
LEVERAGE	1.61 (3.14) ***	-0.98 (-3.63) ***	-0.89 (-3.73) ***
DIV	1.94 (10.21) ***	-1.22 (-13.12) ***	-1.12 (-13.53) ***
CAPEX	-0.17 (-6.24) ***	0.08 (6.03) ***	0.07 (6.05) ***
RND	-2.05 (-5.07) ***	1.28 (5.06) ***	1.10 (4.75) ***
PRICE	-1.29 (-5.36) ***	-0.10 (-1.04)	0.11 (1.19)
RET	-0.17 (-6.18) ***	0.10 (7.79) ***	0.09 (8) ***
NSHAR	0.13 (2.32) **	-0.05 (-1.66) *	-0.06 (-2.13) **
SBAS	0.11 (6.03) ***	-0.05 (-5.53) ***	-0.05 (-5.96) ***
Constant	3.38 (2.05) **	1.39 (2.07) **	0.67 (1.1)
Observations	5026	5026	5026
RSQ	0.39	0.33	0.33
Year FE	YES	YES	YES
Industry FE	YES	YES	YES
Wu-Hausman	59.42	115.16	112.55

Note: This table shows the coefficients and the *t*-statistics (in parentheses) of the regressions estimated over the sample period from Jan 3, 2005 to Aug 31, 2015. ECASH* is the predicted firm excess cash holding and is obtained by regressing individual firm's cash holding on industry excess cash holding. There are three option illiquidity measures: (1) 10 times the log of option proportional bid-ask spread (OBAS); 2) the natural log of yearly total option volume (OVOL); (3) the natural log of yearly total open interest (OI). Wu-Hausman is Durbin–Wu–Hausman test statistics for **e**ndogeneity. Definitions of all variables are reported in Table 1 and Appendix. Observations are the number of firm-year. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables used to control for year and industry fixed effects, respectively. RSQ is the regression R-Squared. The *t*-statistics, which are adjusted for clustering by firm and year, are reported in parentheses. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 5.12 Controlling for Endogeneity

5.6. Conclusion

This study examines the importance of excess cash on option market liquidity across a large number of companies over the period from Jan 3, 2005 to Aug 31, 2015. It presented tests for the night hypotheses developed to provide findings for the empirical research. Table 7.13 presents a summary of the hypothesis testing results and the obtained story, respectively.

Hypothesis	Expected Effect	Result	Obtained Sign
H_1	Higher level of excess cash increases option liquidity.	Supported	+
H_2	Excess cash further increases option liquidity in the firms with a higher degree of information asymmetry.	Supported	+
H_3	Higher level of excess cash decreases option liquidity.	Not	
H_4	Excess cash further decreases option liquidity in the firms with more severe agency conflict problems.	Not	
H_5	Excess cash further increases option liquidity when option traders become more bullish.	Supported	+
H_6	Excess cash further increases option liquidity in volatile markets.	Supported	+
H_7	Excess cash reduces the effect of the increase in option liquidity in volatile markets.	Not	
H_8	Excess cash further increases option liquidity during the financial crisis.	Supported	+
H_9	Excess cash further increases option liquidity in the firms with higher degree of board independence.	Supported	+

Note: This table summarizes the hypothesis test results. The columns of variable show hypothesis number, expected results, empirical results and obtained sign. Column of empirical results includes support hypothesis (Supported), and not support hypothesis (Not). Column of obtained sign includes positive effect (+).

Table 5.13 Summary of the Hypothesis Testing Results

Consistent with the argument by Gopalan *et al.* (2012), our findings corroborate the arguments that excess cash positively affects option market liquidity. Companies with higher excess cash experience lower bid-ask spread, higher trading volume, or greater open interests for their stock options in the secondary markets. We find that the relation is stronger for companies with a higher probability of informed trading or during the financial crisis. These findings reinforce the predictions by Gopalan *et al.* (2012) and Lin *et al*. (2009) that investors are attracted by excess cash due to lower uncertainty in asset value, especially during periods of greater volatility in financial markets. Our results are not consistent with the arguments by Ball *et al*. (2000) and Ball (2006) that excess cash is driven by agency conflicts, and therefore, market liquidity declines in excess cash. Agency determinants, such as the degree of board independence, also strengthen the positive effects of excess cash on option market liquidity.

Our paper also contributes to the extant literature on option market liquidity. Previous studies have provided mounting evidence on the determinants of liquidity in option markets (See, for instance, Cao and Wei, 2010; Verousis *et al*., 2016a). Our paper is the first to document the link between the liquidity of financial options to the level of cash reserves observed in the underlying entities. We show that excess cash significantly explains the variations of option trading volume, open interest, and the quoted spread across companies in addition to other established determinants in the literature. Our research provides suggestions for future studies to examine the effects of excess cash on other derivative instruments, which also account for a significant portion of the trade market, such as European options, CDSs and futures.

In practice, sufficient corporate cash reserves enhance asset market liquidity and retain financial stability, which provides practical implications to policymakers, government and corporations (Bank of England, 2020)[40]. Firstly, policymakers could formulate and implement the policies to increase excess cash in enterprises. Secondly, the government attempt to raise traders' awareness of excess cash, thereby encouraging their investment in cash-rich companies. Thirdly, companies could hold sufficient excess cash to buffer the exposure from a liquidity shortfall and retain financial stability.

[40] See, for example, 'Financial Stability Report', Bank of England, August 2020.

5.7 Appendix

5.7.1 Appendix A: Variable Definitions

This table summarizes the key variables used in this study.

Variable	Definition
ECASH	The residual of a cross-sectional regression of cash holdings on firm characteristics (Eq. (1)).
IECASH	The natural logarithm of the industry average excess cash (ECASH).
MTB	The market value of assets divided by total assets.
SIZE	The natural log of net assets.
DIV	A dummy variable with a value of one if a firm pays dividends and zero,
CAPEX	Capital expenditure scaled by net assets.
LEVER	The ratio of total debt to net assets.
RND	Research and development expenditure scaled by sales.
PRICE	The close price on a stock in a fiscal year.
RET	The stock's holding period return from CRSP.
NSHAR	The natural log of the number of common/ordinary shareholders.
PINDUM	A dummy variable equals one if the probability of informed trading (PIN) measure is above the annual cross-sectional average and zero otherwise.
SBAS	The stock proportional bid-ask spread, which is calculated as the difference between ask and bid divided by the mid-point.
NONEX	The degree of board independence, calculated as the ratio of the number of independent directors and the board of directors
INSIDER	The ratio of the total number of shares traded by insiders (namely, executive directors) to the total number of shares outstanding.

Table 5.14 Variable Definitions

5.7.2 Appendix B: Correlation Matrix

	CASH	ECASH	MTB	SIZE	LEVER	DIV	CAPEX	RND	PRICE	RET	NSHAR	SBAS	OBAS	OI	OVOL
CASH	1														
ECASH	0.47	1													
MTB	-0.13	-0.002	1												
SIZE	-0.47	0.003	0.67	1											
LEVER	0.05	-0.01	0.10	0.16	1										
DIV	-0.27	0.005	0.28	0.44	0.05	1									
CAPEX	0.15	-0.005	-0.10	-0.19	-0.04	-0.10	1								
RND	0.40	0.01	-0.05	-0.20	0.20	-0.16	0.03	1							
PRICE	-0.10	0.02	0.20	0.30	-0.0002	0.18	-0.02	-0.08	1						
RET	0.04	0.004	-0.02	-0.04	-0.01	-0.03	-0.09	-0.01	0.14	1					
NSHAR	-0.25	-0.01	0.43	0.55	0.04	0.41	-0.11	-0.09	0.13	-0.03	1				
SBAS	0.12	-0.09	-0.26	-0.46	-0.05	-0.27	0.08	0.10	-0.39	-0.13	-0.21	1			
OBAS	-0.02	-0.18	-0.30	-0.41	-0.07	-0.06	-0.08	-0.01	-0.15	-0.02	-0.21	0.21	1		
OI	0.06	0.25	0.44	0.53	0.08	0.08	0.09	0.05	0.15	0.05	0.30	-0.27	-0.80	1	
OVOL	0.06	0.25	0.44	0.52	0.07	0.07	0.10	0.04	0.17	0.05	0.28	-0.27	-0.80	0.98	1

Notes: This table shows the the pair-wise correlations of firm characteristics and option liquidity from Jan 3, 2005 to Aug 31, 2015. CASH includes cash and short-term investments scaled by net assets; ECASH is the residual obtained from the regression equation (1), MTB is the ratio of market value of assets to total assets on a basis point; SIZE is the natural logarithm of net assets; LEVER is the ratio of total debt to net assets; DIV is a dummy variable with a value of one if the firm pays dividends, and zero otherwise; CAPEX is 100 times the ratio of capital expenditures to net assets; RND is the ratio of research and development expenditures to sales; PRICE is the stock price divided by 100; RET is 100 times the stock return; NSHAR is the natural logarithm of the ratio of common shareholders to ordinary shareholders, SBAS is proportional bid-ask spread (in basis points). Option liquidity measures are: OBAS is option proportional bid-ask spread (in percentage points); OVOL is the log of option volume (million); OI is the log of open interest (million). Except option liquidity measures, the values of other variables are lagged in one year.

Table 5.15 Correlation Matrix of Excess Cash, Option Liquidity and Other Variables

Chapter 6 Literature Review of Stock and Equity Option Illiquidity Linkages

There are three parts in this chapter. The first part explains why funding liquidity is the crucial source of multiple asset market liquidity linkages (Brunnermeier and Pedersen, 2009). The second part will sub-divide into small sections discussing the different hedging mechanisms of multiple asset market liquidity linkages, including asymmetric information and inventory risks (Cho and Engle, 1999; Huh *et al*., 2015). The last part mainly focuses on demand-based pricing theory (Garleanu *et al*., 2009) and introduces an option-induced demand mechanism.

6.1. The Funding Mechanism of Cross-Market Liquidity Linkages

This section presents the theoretical and empirical studies in the funding mechanism of the cross-market liquidity linkages. First, the theoretical framework of funding liquidity and market liquidity will be discussed. Secondly, funding liquidity and market liquidity linkages will be empirically analysed.

Theoretically, the relationship between funding and market liquidity is mainly based on Brunnermeier and Pedersen (2009) framework, which proposed that the traders, who are constrained by funding, cannot fully provide liquidity to the market. Because of these financial limitations, the causal effect will be established related to funding liquidity on market liquidity as aggregate traders lacking adequate funding. The failure of these funding constrained traders leads to a causal effect from funding liquidity on market liquidity. This situation is particularly pronounced in the event of a financial crisis. During the crisis, the firms experience enormous financial constraints and expose to giant volatility risk. Consequently, this will create the disaster of asset fire-sale and force the liquidity to withdraw fiercely. Furthermore, the funding risk and fire-sales effects establish the liquidity linkages across different asset markets (Marra, 2016). The empirical research reveals the evidence in the equity and derivatives markets about this story (Comerton-Forde *et al*., 2010; Hameed *et al*., 2010; Ben-David *et al*., 2012; Jylha, 2018; Marra, 2016).

These theoretical and empirical studies provided explanations of the funding mechanism for the cross-market liquidity linkages. Based on the previous funding literature, this part systematically analyses the equity-equity option market liquidity interactions and investigates the role of funding liquidity on these two market liquidity interactions.

This part reviews the literature concerning the aspect of funding liquidity. First, the theoretical frameworks of funding liquidity and market liquidity will be discussed. Following Brunnermeier and Pedersen (2009), funding liquidity is an important source of market liquidity. Secondly, the relationship between funding liquidity and market liquidity linkages across equity and equity option markets will be empirically analysed.

6.1.1 Funding Theory

In the aftermath of market declines, market makers attempt to absorb market liquidity shocks to make market but constrained by their funding. There are two major approaches for them to acquire financing resources, which are 'posting margins and pledging the securities they hold as collateral' in the capital-based theory (Hameed *et al.*, 2010). Under the pressure of the significantly falling market prices, some financial intermediaries, however, reach their margin limits. They have no other means but to liquidate their positions across many assets and reduce market liquidity supply. In the end, tight funding constraints will enhance liquidity commonality across assets by decreasing their liquidity supply. This part will theoretically investigate the role of trading capital in asset market liquidity.

1) Funding Capital of Financial Intermediaries: The Supply of Market Liquidity

Earlier studies, such as Xiong (2001) and Kyle and Xiong (2001), proposed contagion and amplification mechanism[41], which origin from 'arbitrageurs' wealth-dependent risk aversion rather than financial constraints', to explain arbitrageurs' trading (Gromb and Vayanos, 2010). Different from their contagion and amplification arguments, Gromb and Vayanos (2002) highlighted the decisive role of financial intermediaries' capital availability in the market liquidity. Arbitrageurs perform the role of intermediaries. They take advantage of price

[41] Contagion mechanism in which volatility is transmitted from one market to another, origins from the arbitrageurs' increasing demand for risky assets in wealth. When these traders are subjected to large capital losses, they are forced to unwind their positions in the whole portfolio. Eventually, these fundamentally unrelated asset prices fluctuate together. Furthermore, in amplification mechanism, when traders experience wealth constraints, their convergence trading causes a rise in price volatility, a drop in the market liquidity, and a more serious destabilizing price situation.

differences to facilitate transactions among the other investors, thereby supplying liquidity. Arbitrageurs with sufficient capital have ability to fully absorb supply shocks from other investors to provide market liquidity. If they are constrained by limited capital, they will have lower risk-bearing capacity against shocks and become more difficult to supply market liquidity.

Anshuman and Viswanathan (2005) analysed the views of leverage investors (i.e., the investors who buy on margin) when they provide market liquidity. In general speaking, a market downturn devalues the collateral of leveraged investors and then reduces their liquidity provision. As highly leveraged investors are more likely to have uncollateralised positions, the falling asset values compel them to provide collateral which easily causes endogenously default. Eventually, asset liquidation triggers and thereby, market liquidity declines. However, Anshuman and Viswanathan (2005) proposed the leverage investors' ability to renegotiate constraints which facilitates them to eliminate liquidity crises unless several frictions present. Yet, in practice, the existence of friction implies that renegotiation is not an efficient method to eliminate these crises (Acharya and Viswanathan, 2011). Simultaneously, market makers reduce the funding for assets they possess in the repo market, implying that they are financially constrained. More importantly, their limited funding capability exacerbates the reduction in the market liquidity provision.

Although the role of individual investors (or institutions) in liquidity provision received great attention from existing studies, a minority of papers contend that the importance of an interconnected banking system should be widely considered. The liquidity risk is transmitted from a financial institution to other institutions through the inter-banking system. Individual investors or institutions with sufficient capital are skilled and specialised in protecting themselves from illiquidity shocks, such as by inter-banking loans. An inter-bank loan allows them to access liquidity to provide insurance and stability. In a different situation, the interconnected banking system is a transmission mechanism of the financial crisis. Cifuentes *et al*. (2005) highlighted the liquidity risk in an inter-banking system. An idiosyncratic shock decreases the market value on the balance sheet and then forces the bank to sell liquid assets to maintain its solvency. In other words, a distressed bank sells its illiquid assets to maintain its solvency. The falling of illiquid asset price urges the bank to default, which will create the ripple effect causing other banks to go into distress. In the end, the bank default exerts negative effects on the fund of individual institutions and reduces market liquidity provision.

Furthermore, the growing cost of intermediation, caused by the slow movement of investment capital, reduces market liquidity in terms of bid-ask spread in the 2008 financial crisis (Duffie, 2010). Duffie (2012) further demonstrated that this crisis adversely affects the functioning of the bank lending channel and market liquidity. It is costly for investors and issuers of securities to obtain more fund and higher liquidity for their existing positions.

By analysing different types of investors and inter-banking system, research results discovered that risk management mutually interacts with market liquidity (Garleanu and Pedersen, 2007). Regarding the institutional investors risk-bearing capacity, the higher volatility in market recession causes them to have less capacity to tackle these circumstances. Besides this, institutional investors reduce the liquidity provision because of tighter risk management and lower market liquidity. More importantly, there is positive feedback between market liquidity reduction and tightens risk management.

On the whole, these theoretical studies pointed out that falling stock returns create a smaller pool of capital relative to considerable stocks. In this situation, market makers and other financial intermediaries, such as arbitrageurs, leveraged investors, interconnected banking system, are subjected to capital constraints, so the supply of liquidity will decrease. Corporations also tighten risk management to provide less liquidity.

2) The Relationship between Funding Liquidity and Market Liquidity Linkages across Multiple Assets

Previous literature, including the Shleifer and Vishny (1997) and Gromb and Vayanos (2002), revealed that financial constraints of arbitrageurs affect market liquidity [42]. Arbitrageurs absorb supply shocks from other investors and then provide market liquidity. If arbitrageurs with limited financial resources cannot eliminate price dislocations, they will provide less market liquidity and overall market liquidity decreases (Gromb and Vayanos, 2002). The insufficient knowledge

[42] Market liquidity is the ease of the assets traded (Jylha, 2018).

of arbitrage causes investors to misestimate the arbitrageurs' competency and limit the pool of capital available to them (Shleifer and Vishny, 1997).

Consistent with the previous arguments related to arbitrageur's limitation, Gromb and Vayanos (2010) supported that the connection across independent assets is established by the arbitrageurs' financial constraints. For example, market liquidity is influenced by the fundamental and supply shocks to arbitrageurs' investment opportunity. Furthermore, it also showed that non-fundamental demand shocks, such as the information or agency problems vis-à-vis investors, force arbitrageurs to have a limited amount of fund. Funding-constrained arbitrageurs cannot provide liquidity to other investors and thus create cross-market liquidity linkages.

After introducing the funding liquidity [43], recent theoretical research on the funding-market liquidity interaction further explained the severe liquidity reduction when the market declines (Brunnermeier and Pedersen, 2009; Acharya and Viswanathan, 2011). The nature of this financial phenomenon is that financial constraints[44] influence the trading strategies of investors, and eventually create a systematic source of liquidity fluctuations across financial assets. The funding shocks impair liquidity provision and reinforce the multiple asset market liquidity linkages.

A theoretical model was established by Brunnermeier and Pedersen (2009) to show that funding constraints affect both market liquidity and asset prices. Financial intermediaries face funding constraints and have difficulties raising funding, sell or pledge assets. They are forced by the financial distress to liquidate their positions across multiple asset markets to recover from these losses. This liquidation produces the joint effects of asset and funding liquidity (namely, liquidity spiral) when the market experiences downturns. In short, funding liquidity as one of the supply-side factors plays an important role in the market liquidity interactions across assets.

[43] Funding liquidity is 'the willingness of financiers to provide such loans' (Boudt *et al*., 2017).
[44] Financial constraints represent inadequate access to venture capital (Cusmano, 2015), inflation (Finocchiaro *et al*., 2018), and increasing interest rates (Saghir and Aston, 2017). These financial constraints are also documented in the financial media See, for instance, Chron "What Constraints Are Placed on Business in the Economy".

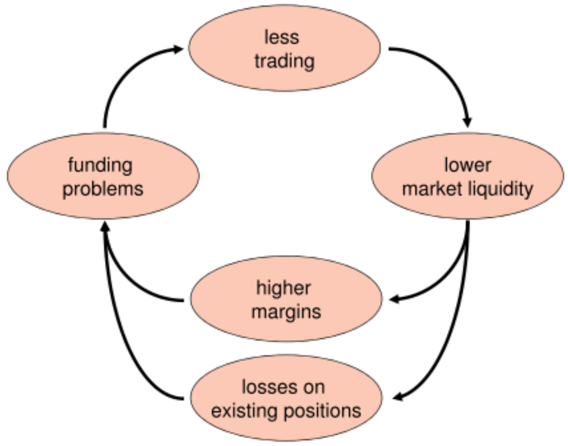


Figure 6.1 Liquidity Spirals

Sourced from: Brunnermeier and Pedersen (2009)

Figure 6.1 illustrates liquidity spirals. ‘When asset and funding liquidity risks join together, a liquidity spiral — or a cycle where attempts to secure additional liquidity come at an increasing cost and a decreasing level of flexibility — can develop. Once a liquidity spiral has commenced, each new attempt to source cash becomes more critical, difficult, and costly. A company caught in a spiral must deal forcefully with the crisis or risk sliding into financial distress and possible insolvency’ (Banks, 2014).

Furthermore, a new explanation for liquidity dry ups in the extreme market downturn, namely, the heterogeneity of institutions’ response to the crisis, was propounded by Acharya and Viswanathan (2011). Financial constrained institutions decrease their leverage by selling assets to other institutions with financial slack. The institutions with less financial constraints invest their asset purchases by increasing short-term debt. In a different situation, the adverse information about the asset’s prospects, arising from the risk-shifting moral hazard, affect the lenders’ rational financing. A connection between the capital supply and the institution’s ability to supply liquidity in an asset is built by the lenders’ credit rationing. Therefore, adverse asset shocks cause de-leveraging, and the market return declines suddenly. In the end, funding liquidity will dry up.

To sum up, a substantial market downturn reduces the ease to obtain funding (namely, funding liquidity). Financial intermediaries are reluctant by the stringent funding constraints to take on their positions, thereby decreasing market liquidity. Put it simply, a deterioration in funding liquidity lowers asset market liquidity, which creates market liquidity linkages.

3) The Relationship between Funding Constraints and Other Market Imperfections

In the absence of discrepancies between internal and external financing, each of these financings is regarded as substitutes. Theoretically, there are no binding financial constraints in a perfect market (Modigliani and Miller, 1958). Nevertheless, when external financing costs are higher than that of internal counterparts, the extent of financial constraints will become tighter in a frictional market. (Fazzari and Athey, 1987; Kaplan and Zingales, 1997). As financial constraints significantly distort the projects related to corporate value creation, several factors have been explored to help overcome financial difficulties (Meng *et al*., 2020). This part examines two factors in-depth, which are information asymmetry (Diamond and Verrecchia, 1991) and short sales (Meng *et al*., 2020).

a) Information Asymmetry

In the presence of informed investors with investment constraints, a linkage between asymmetric information and market liquidity was established in Yuan (2005). Although being aware of the signals flashed by the stock price behaviour, the arbitrage ability of informed traders is limited by the binding borrowing constraints so that less informative stock price cannot fully reflect their investment decisions. Regarding the uninformed investors perspective, they will depreciate the asset value more than that it drops. If this is the case, the asset price will be crashed even though there is an absence of public news that will transmit to other markets disproportionately. Under pressure from price drops, governments will intervene in the market by supplying liquidity, thereby easing borrowing constraints.

A similar explanation of the relationship between asymmetric information and investment constraints was proposed by Albagli (2011). Capital-constrained agents expect that future demand shocks will contribute significantly to determining stock prices but cannot trade aggressively based on their informational signals of economic fundamentals in financial distress, such as productivity and conditions from stock prices. Under this circumstance, agents cannot acquire adequate information from the relevant stock prices, thus causing a lack of willingness of future agents to absorb demand shocks.

In contrast to the previous literature about information acquisition when the capital sources of traders are constrained, Glebkin *et al*. (2018) presented a theoretical framework of an interaction between the funding constraint tightness and informational efficiency, namely, information spiral [45]. It had two important implications for this information spiral in the stock market. Firstly, the channel of financial constraints influencing informational efficiency is that the decline in wealth impedes information collection and hinders informational efficiency. Binding funding constraints force traders to take smaller positions and reduce their profits on their private information. As the expected profit range decreases, they become less engaged to acquire as much information as possible and access lesser information as a result. In short, this causes prices to convey less informational signal about asset fundamentals.

Secondly, based on Brunnermeier and Pedersen (2009) assumption that traders finance their positions by relying on collateralized borrowing, which is restricted by the margin requirements from the financier. Furthermore, this situation will establish the reverse channel of informational efficiency in which the reduced informational efficiency tightens margins (investors' constraints). Due to the less informative prices, financiers set higher margins in the face of increasing uncertainty about fundamentals from their high-risk trading activities. Based on all the above reasonings, this mutual interdependent relationship leads to an information-based amplification mechanism (that is, information spiral), which is shown as the following graph:

[45] 'Investors' funding both affects and is affected by informational efficiency, which leads to a novel amplification mechanism that we call the information spiral.'

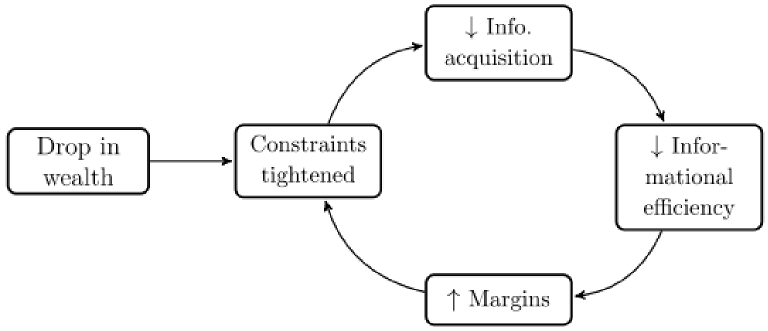


Figure 6.2 Information Spiral

Sourced from: Glebkin *et al.* (2018)

Notes: When we combine these analyses, our model yields two key implications. First, tighter funding constraints reduce the information acquired by investors, which reduces informational efficiency; second, reduced informational efficiency leads to higher margins, which tightens investors' constraints. This interdependence gives rise to an information-based amplification mechanism, illustrated in Figure 4.2 that we call the information spiral.

b) Short Sales

In addition to information asymmetry, short sales also play an important role in financial constraints. According to the conceptual frameworks of short sales in Meng *et al.* (2020), when short-selling constraints occur, the outcomes for the financial constraints are conflicting. These resulting multiple effects are called the negative information effect, the undervaluation effect, and the deterrent effect. Based on the literature related to these three effects, there are two competing theoretical arguments about the relationship between short sales and financial constraints. In studies on the negative information effect and the undervaluation effect views, short selling exacerbates the firm's financial strains. By contrast, the studies based on the deterrent effect ground conjectured the opposite relationship.

The aggravated effects of short selling on financial constraints can be supported by the negative information effect. Short sellers are assumed to be informed traders and are skilled at capturing particular information. This is because they would never initiate a short position for liquidity reasons (Miller, 1977, Diamond and Verrecchia, 1987). However, most traders who obsess pessimistic about the market prospects are shut out of the market. Short sales restriction limits the reaction of stock prices to a firm's negative outlook (Jones and Lamont, 2002; Engelberg *et al.*, 2012). After the deregulations of short sales, short sellers engage in their shorting activities and then uncover and disseminate adverse news to the market (Christophe *et al.*, 2004, 2010; Karpoff and Lou, 2010). Consistent with Hirshleifer *et al.* (2011), Khan and Lu (2013) and Chakrabarty and Shkilko (2013), the speed of accessing the firm- and market-level information is accelerated, and this information will be reflected in the stock prices. Eventually, a firm's cost of equity required by investors (external financing cost) increases tremendously, and this firm's financial constraints worsen (Gilchrist *et al.*, 2005; Grullon *et al.*, 2015).

This aggravated-effects hypothesis is also interpreted by the undervaluation effect. In this alternative channel, short sellers are expected to be less informed. Their short-selling strategies, including the direct attacks (Goldstein and Guembel, 2008), value-destroying investment decisions (Goldstein *et al*., 2013) and negative emotional transmission (Maffett *et al*., 2017), have both directly and indirectly negative consequences for the stock price. There are substantial concerns from the investors about the firm's prospect, which is driven by the stock price distortion and firm value. As a result, investors suffer from the high costs of equity and debt. In short, the undervaluation of firm fundamentals arouses external financing costs, thereby blinding a firm's financial constraints after the deregulation of short sales (Kaplan and Zingales, 1997).

By contrast, the alleviated effects of short selling on financial constraints can be explained by the deterrent effect. The role of short sales in disciplining managers' opportunistic behaviours to reap their private benefits is recognized in this hypothesis (Chang *et al.*, 2014). Due to the release of adverse information, the reputational and pecuniary losses of managers are amplified by the threat from short sales (Bernanke and Gertler, 1989). Finally, the reduced agency problem between managers and shareholders causes financial constraints to be less stringent (Gertler, 1992).

To sum up, financial constraints are closely associated with other market imperfections, such as asymmetric information and short-selling constraints (Vayanos and Wang, 2013). As financial constraints weaken liquidity provision and then enhance the liquidity linkages across multiple asset markets (Brunnermeier and Pedersen, 2009), information asymmetry and short sales are expected to be the driving forces of multiple-asset market liquidity linkages.

6.1.2 The Empirical Studies of Funding liquidity and Asset Market Liquidity Linkage

The theoretical literature (e.g., Brunnermeier and Pedersen, 2009) relating assets market liquidity to the funding conditions of an intermediary received a great deal of empirical support. The empirical literature investigating the effects of funding constraints on market liquidity documented the evidence in line with the funding liquidity risk channel in multiple asset markets. This part particularly provides empirical evidence in the equity and equity option markets.

1) The Empirical Studies of Funding liquidity and Equity Market Liquidity Linkage

Large and growing studies on liquidity linkages across multiple asset classes empirically support the funding theories, especially in stock markets. Empirical results related to different types of liquidity linkages, including flight to liquidity (Pastor and Stambaugh, 2003), liquidity in commonality (namely, liquidity co-movement) (Chordia *et al.*, 2000) and liquidity spillover (namely, liquidity contagion) (Marra, 2011), are accordance with the supply-side source argument of funding liquidity (e.g., Brunnermeier and Pedersen, 2009).

a) Flight to Liquidity

Flight to liquidity refers to the increase of liquidity differential between high-volatility and low-volatility stocks with the dealer's capital deteriorations. The findings of Pastor and Stambaugh (2003) supported the argument of flight to liquidity and the pricing of this liquidity risk. Additionally, Acharya and Pedersen (2005) showed that the drops in the aggregate market liquidity are mostly driven by illiquid assets, which is also in accordance with flight to liquidity notion. Based on these studies, the reason behind this financial phenomenon is that lower-margin stocks are less volatile. Capital constrained traders are prone to supply liquidity in stocks that are not capital intensive. Therefore, illiquid stocks are at greater liquidity risk. The studies on flight to liquidity were consistent with the theoretical argument of Brunnermeier and Pedersen (2009) that was generated from the interaction between market liquidity and funding liquidity (given by the capital and margin requirements of traders).

b) Commonality in Liquidity

Liquidity commonality is defined as ‘the proportion of how much a firm’s liquidity is at least partly explained by the market-wide and industry-wide factors’ (Syamala *et al*., 2014). Mounting empirical studies documented the presence of liquidity commonality and their supply-sided factors.

Earlier literature focused on liquidity commonality across different asset classes, but do not point out their supply-sided sources. Taking Chordia *et al***.** (2000) as an example, it is the first paper to introduce the market-wide characteristics in stock liquidity (namely, commonality in liquidity). In the time-series analysis, the variance in individual liquidity is relevant with industry and market activities over time when the trading activity of individual stocks is controlled. Then it performed the cross-sectional models to show the contributors of this commonality, such as inventory risk and information asymmetry. Lastly, the liquidity covariance of portfolios is more significant than that of individual stocks, owing to the analogy in the assets. Furthermore, the commonality in Chordia *et al*. (2005) further investigated co-movement in liquidity in different asset markets, including equities and bonds. Monetary expansions, defined as higher money flows (‘bank reserves, federal funds rates, and mutual fund investments’), promote positively correlated trading activities in terms of higher order inflows, increased systematic wealth and larger informational shocks. Thus, these primitive sources drive stock-bond market liquidity co-movements.

After confirming the presence of the commonality of stock market liquidity (Hasbrouck and Seppi, 2001; Huberman and Halka, 2001), some studies turned to explore the role of funding liquidity in the commonality in liquidity. For instance, Coughenour and Saad (2004) investigated how capital constraints influence commonality in stock liquidity. It found that liquidity commonality is stronger for the stocks traded by the financially constrained NYSE specialist firms. The resource sharing patterns among these firms are reflected in many ways, such as the combinations of capital, profit and loss information and inventory. Their higher degree of resource sharing leads to the common adjustments to liquidity provision. These firms supply liquidity for a large number of stocks, so their liquidity co-movement increases. Put it simply, Coughenour and Saad (2004) provided empirical evidence to the funding-liquidity mechanism, in which the level of stock liquidity co-variance can arise from the tighter funding constraints faced by these NYSE firms.

In addition, reduced funding liquidity increases commonality in stock liquidity during market downturns. The empirical findings of Hameed *et al*. (2010) were in accordance with an argument that the supply of liquidity is diminished following a stock market decline (Garleanu and Pedersen, 2007; Brunnermeier and Pedersen, 2009). To broaden the investigation of liquidity co-variance, Hameed *et al*. (2010) put forwarded a new view as ‘interindustry spillover effects in liquidity’. If liquidity commonality is initiated by the market makers who encounter capital constrain in providing liquidity, a rise in correlated illiquidity in one industry is associated with the falling stock market value in other industries. Due to the occurrence of significant negative market returns, capital constraints become tighter and liquidity supply decrease. At last, liquidity spillover effects spread throughout the industries and then drives the liquidity commonality in the stock market.

Furthermore, funding risk creates liquidity linkages across assets. Comerton-Forde *et al.* (2010) presented supportive evidence that financing constraints generate an association between inventory and stock liquidity with risk-averse market makers. Capital constraints proxied by the higher inventory aggregate inventory holdings in NYSE are used to determine the aggregate stock market liquidity. The higher aggregate inventory of all NYSE specialists reduces market liquidity and binds after market declines, thereby producing liquidity commonality. It is in accordance with the Brunnermeier and Pedersen (2009) supply-side argument that due to the tighter funding liquidity, investors are less willing to take on ‘capital intensive’ positions in high-margin stocks than other positions. Because of the investor averse attitudes, this leads the market liquidity to decrease as a result.

These empirical studies supported the supply-side liquidity argument proposed by Brunnermeier and Pedersen (2009). However, the results of Karolyi *et al.* (2012) were inconsistent with this theoretical conclusion and did not find support for the significant role of capital constraint in the stock liquidity commonality. This study found that demand-side factors of liquidity are important determinants of commonality in liquidity, such as investor sentiment, the correlated trading behaviours of institutional investors and the motivations of investors to trade individual securities.

In contrast to Karolyi *et al.* (2012), recent empirical studies conferred robustly and consistently supported the supply-side source of commonality in liquidity. For instance, in Syamala and Reddy (2013), there exists a considerably positive size effect on liquidity commonality. If firm size increases, this commonality will rise. Additionally, supply-side sources are proved to be the most essential determinants of liquidity commonality. Similarly, Rösch and Kaserer (2013) showed that funding liquidity tightness enhances commonality in liquidity and exacerbates the market-wide liquidity dry-ups, especially during market declines. It supported the argument of the liquidity spiral as in Brunnermeier and Pedersen (2009). Market downturns destabilize margins and then lead to the mutual reinforcement between funding and market liquidity. At last, this reinforcement creates a liquidity spiral effect. The commonality in liquidity at least partially results from the funding and market liquidity spiral.

c) Liquidity Spillover Effect

For the dynamic relationship of market illiquidity, a few studies focused on illiquidity spillover effects in asset markets (Qiao *et al*., 2020). 'Illiquidity spillovers imply illiquidity commonality, but illiquidity commonality does not necessarily imply the existence of spillovers' (Marra, 2011). Illiquidity spillover across multiple asset markets and the mutual impact of illiquidity conditions are strongly associated with the studies that regard illiquidity as a risk factor in asset market (Goyenko and Ukhov, 2009). When illiquidity is a systematic factor and is taken into consideration in investors' decisions, the investors will allocate their portfolio in the different fashions and include illiquidity market conditions as one of the crucial factors. Under this situation, we expect that illiquidity will have an effect across multiple asset markets.

The empirical investigation of liquidity spillovers is restricted in the stock market and is conducted by Brockman *et al*. (2009). Their research selected intraday spread and depth data from 47 stock exchanges to show that commonality in liquidity plays a pervasive role within individual exchanges. Local (exchange-level) sources of liquidity commonality account for about

39% of the commonality at the firm level, while global sources make up an additional 19% proportion. Additionally, it also documented strong liquidity spillovers across different firms and exchanges. Liquidity spillovers become more significant in the spread dimension, but more complicated for depths in stock markets.

Some studies extended liquidity spillover effects to multiple asset markets, such as equity and bond markets (Goyenko and Ukhov, 2009). There are some reasons to explain the presence of illiquidity spillover in stock and bond markets. For instance, some similarities can be found in stock and bond market illiquidity, such as investors' ability to purchase or sell large amounts of assets quickly and cheaply. In addition, the volatility of these two markets is closely linked (Fleming *et al*., 1998). Volatility changes market makers' inventory risk and then influence both market illiquidity (Ho and Stoll, 1983; O'Hara and Oldfield, 1986). Furthermore, trading activity also affects stock-bond market liquidity interactions. Due to asset allocation strategies, wealth shifts between these two markets (Fox, 1999; Swensen, 2000).

According to these reasons, Goyenko and Ukhov (2009) created the illiquidity spillover between stock and Treasury bond markets in the US between 1962 and 2003, along with the episodes of flight-to-quality and flight-to-liquidity. The bidirectional Granger causality tests demonstrated the mutual effects of these two assets' illiquidity conditions. Additionally, fund flows (federal funds rate), regarded as an indicator of monetary policy, are a driving factor of stock-bond illiquidity linkages. As bond illiquidity captures the information signal from monetary policy more quickly than stock illiquidity, the shocks of monetary policy transmit from bond illiquidity to equity illiquidity. Hence, a close association between monetary policy and asset market illiquidity linkages is established. Market illiquidity increases with the tightening monetary policy. More specifically, short-term bond illiquidity is more sensitive to the shocks of monetary policy than medium- and long-term bonds.

Additionally, Marra (2016) showed the credit default swaps (CDS)-equity illiquidity co-movements which become stronger in crisis through funding channel and the hedging–arbitrage channel. In the funding channel, funding costs, market volatility and systematic risk are three main determinants of their illiquidity linkages. The linkages are pronounced when the magnitudes of these determinants increase. For instance, insufficient financial resources or high market risk compel traders to withdraw their positions so that stock and CDS market liquidity declines, and their liquidity costs increase. In the 2007-2009 financial crisis, the lack of traders' funding capital exacerbates CDS-equity market illiquidity contagion episodes.

In hedging–arbitrage channel, higher hedging costs, greater information asymmetry risk, and larger CDS-equity mispricing contribute to the growing CDS bid-ask spreads. Banks act as risk averse CDS dealers to hedge their CDS exposures in the stock market. Hedging costs are calculated as the multiplication of the hedge ratio and equity bid-ask spread, implying that a higher hedging ratio causes hedging costs to represent a larger part of the CDS spread. Hence, banks adjust the bid-ask spread of CDS to recover hedging costs. Higher asymmetric information risk increases hedging activities and sends a negative signal to equity dealers. In response to the negative information flows, these dealers increase equity spread to protect themselves against potential exposure, further increasing CDS spread. Additionally, because of information asymmetry across the correlated asset market, temporary CDS-equity mispricing encourages informed arbitrage trading across CDS and equity markets. A firm-specific shock increases CDS and equity spreads when uninformed equity and CDS dealers protect themselves from the informed trading with sophisticated arbitrageurs in order to achieve the risk reduction effect. As a result, the equity-CDS illiquidity interaction increases further.

In conclusion, funding constraints become more stringent in the market downturn, which reduces funding liquidity. Under this circumstance, different type of stock liquidity linkages in the forms of flight to liquidity, liquidity in commonality and liquidity spillover strengthen gradually.

2) The Empirical Studies of Funding liquidity and Option Market Liquidity Linkage

Mounting empirical evidence of funding and market liquidity was restricted in stock markets; little known was about derivatives, such as commodity futures, credit default swaps and equity options. Recent research on the interaction between funding liquidity and derivative market liquidity received increasing attention (Marshal *et al.*, 2013; Marra, 2016; Jylha, 2018). This part focuses exclusively on analysing this funding-market liquidity interaction in the equity option markets.

Earlier studies found the existence of option liquidity commonality but did not take the role of funding liquidity into consideration. Inspired by the study of Chordia *et al.* (2000), Cao and Wei (2010) are the first paper to introduce the liquidity commonality (namely, covariation in liquidity) in option markets. Option market liquidity is closely associated with firm size and underlying stock performances with three different aspects, including liquidity, volatility and returns. Their research also comprehensively analysed the influencing factors of option market liquidity, such as inventory risk and information asymmetry. To be more specific, information asymmetry is more important than inventory risk in enhancing option market liquidity.

Contradictory to the study of developed quote-driven option market (Cao and Wei, 2010), Syamala *et al*. (2014) extended the research to the liquidity commonality across equities and equity options in the emerging order-driven market. Based on the Chordia *et al*. (2000) model, there is a strong market- and industry-wide option liquidity commonality after controlling for the underlying stock market liquidity and implied volatility. In comparison with the stock market, commonality in option liquidity appears to grow at a faster rate with market capitalization. Additionally, information asymmetry is a driving factor of liquidity commonality across these two asset markets. Market-level information asymmetry exerts more significant effects on stock liquidity than industry-wide asymmetric information. For option liquidity, commonality in call options is higher than put options.

Option liquidity spillovers were widely discussed in the empirical literature. For instance, Verousis *et al.* (2016b) used intraday data to find liquidity commonality in European option markets from 2008 to 2010. It becomes more apparent throughout the time of the higher market-wide implied volatility and tighter short-sale restrictions than normal time. Idiosyncratic characteristics of options, including underlying stock liquidity, have strong explanatory power of this liquidity commonality. Additionally, commonality in option liquidity spillovers is witnessed across three European exchanges in Amsterdam, Paris, and London. The option liquidity interconnectedness of the home market with other markets is shown in this study.

Liquidity spillovers in Verousis *et al.* (2016b) were only restricted in the option market, but Li (2016) extended this effect to multiple asset markets, including equity options, warrants and underlying equity markets in Hong Kong between 2005 and 2006. According to the derivative hedging theory proposed by Cho and Engle (1999), it demonstrated that derivative liquidity has an inverse connection with derivative market makers' hedge ability in the underlying market, which is proxied as underlying asset market liquidity. Option liquidity positively relates to underlying stock liquidity. Furthermore, the presence of liquidity spillover from the underlying stocks to the derivatives (e.g., equity options, warrants) is exhibited. Low market liquidity and high inventory risk in derivatives cause the high propensity to hedge in underlying stocks, thereby promoting underlying stock market liquidity spill-overs to the derivative market liquidity.

Previous studies showed the presence of option liquidity commonality and liquidity spillover effects, but the supply-sided source in option markets received sparse attention. Liu *et al.* (2018) and Jylha (2018) further investigated the role of funding liquidity in option market liquidity. For example, Liu *et al.* (2018) examined the role of funding liquidity in S&P 500 index option market liquidity. It proxied TED spread as funding liquidity and the proportional bid-ask spread as option liquidity. It showed that the declines of market liquidity occurred with high funding costs, which liquidity providers face in the high market uncertainty (Brunnermeier and Pedersen, 2009). The positive relationship between these two liquidities is more significant when the market is highly uncertain. More specifically, funding liquidity is significantly positively linked to put option liquidity, but marginally significant for call liquidity. In addition to this, this article controlled for stock market liquidity in the Autoregressive-moving average (ARMAX) regressions to examine whether funding liquidity still survives. After controlling for stock market liquidity, a positive relationship between option market liquidity and funding liquidity is found. It is in accordance with the argument of liquidity spirals as in Brunnermeier and Pedersen (2009), the interaction of the market and funding liquidity establishes an interdependence relationship between the two-asset market liquidity.

In consistent with both articles of Gromb and Vayanos (2002) and Brunnermeier and Pedersen (2009), the funding constraints of traders lead to their inability to supply liquidity to markets fully. That is the reason why funding liquidity has a causal relationship with market liquidity. Jylha (2018) is the first article to provide clear and robust causal results that funding liquidity indeed is a driving factor of index option market liquidity. It chose a purely exogenous shock to the securities' margin requirements as funding liquidity. On this basis, raising funding liquidity will cause trading volume escalation, the reduction of bid-ask spread as well as the lower price impacts of trading for index options.

In summary, taking account of equity market uncertainty and market liquidity, funding liquidity is found to be a key driver of option market liquidity in the previous empirical literature. These findings match with the theoretical arguments proposed by Brunnermeier and Pedersen (2009). In market recessions, option market liquidity becomes more sensitive to the higher funding liquidity.

This part presents the funding mechanism for the multiple-asset market liquidity linkages and highlights the role of funding liquidity in these relationships. Mounting empirical literature concentrated on the stock liquidity. Recent researchers shed their lights on the equity derivatives markets, such as the equity option market. After accounting for underlying stock liquidity, equity option market liquidity linkage was systematically analysed in these studies (e.g., Liu *et al*., 2018; Jylha, 2018). As far as we know, few studies placed underlying equities in an equal position as equity options. Consistent with funding theories, we aim to empirically analyse equity-equity option market liquidity transmissions in both directions to bridge this gap.

Additionally, as financial constraints are closely related to information asymmetry and short sales, there is a theoretical gap for the significant effects of these two factors on the market liquidity linkages. Previous empirical studies pointed out information asymmetry, and short sales significantly influence stock (Chordia *et al*., 2000; Billingsley and Kovacs, 2011) and option market liquidity (Cao and Wei, 2010; Verousis *et al.*, 2016a), separately. In a different way, few papers systematically examined these effects on both market liquidity interactions across equities and equity options. Therefore, based on the funding arguments, we will highlight the roles of information asymmetry and short sales in the equity-equity option market liquidity interactions.

6.2. The Hedging Mechanism of Cross-Market Liquidity Linkages

Option market makers (OMMs) tend to hedge their option positions when making markets for option contracts (or other derivative instruments). This is because OMMs not only protect themselves from inventory-carrying risk but also hedge against the asymmetric information risk arising from their trades with informed traders. Regarding these OMMs' trading activities with hedging purposes, it exerts pressure on the two assets spread, which are used for hedging and hedge planning, respectively. Furthermore, option trading creates extra transactions in excess of their needs for market-making. As a result, due to OMMs' hedging activities, their transaction costs are reflected in the bid-ask prices of the assets in any cases (Huh *et al.*, 2015). For instance, OMMs implement dynamic hedging strategies using underlying assets to hedge their net option positions. It is noteworthy to mention that a market-neutral strategy requires frequent trading, which causes significantly high transaction costs and applies only to OMMs who delta-hedge portfolios with a single transaction in the underlying equity markets (Cox and Rubinstein, 1985; Hull, 2003; McDonald, 2006).

6.2.1 Inventory Risk

The extant literature focused primarily on the sources of option liquidity and found that the underlying market trading activities affect option liquidity. Yet, the academic research insufficiently investigated the aspect of whether underlying stock market liquidity affects option market liquidity. As mentioned by Cho and Engle (1999), increasing spreads are caused by the underlying market illiquidity rather than caused by inventory risk or informed trading in the option market itself. It is the first paper to propose derivative hedge theory which provided theoretical foundation of the stock liquidity spillover effects on option liquidity. Bid-ask spreads of derivatives are negatively related to the hedging ability of market-making positions in the underlying market, measured as the underlying market liquidity. The empirical findings indicated that the bid-ask spread of S&P 100 index options is positive to the proportional spread of the underlying stocks. More than that, option market duration influences spreads substantially. Both slow and fast option markets cause spreads to be bigger. In the real world, option market maker can only imperfectly hedge his positions in the underlying stock market. Based on the derivative hedge theory (Cho and Engle, 1999), the following part will mainly discuss how underlying stock liquidity spills over option liquidity.

1) The Relationship between Underlying Stock Trading Activities and Option Liquidity

Extensive studies covered the topic of stock liquidity; however, the studies of equity option liquidity are rather limited. The stylised facts of option market liquidity were demonstrated in the earlier literature. Vijh (1990) showed that Chicago Board Options Exchange (CBOE) options are traded with greater market depth but large bid-ask spreads. 'The absence of price effects surrounding large option trades' implies that there is a greater option market depth. If market depth is not considered, the CBOE option spread is almost equivalent to the New York Stock Exchange (NYSE) stock spread. The trade-off between option and stock market depth and bid-ask spread stems from the market mechanisms' differences. George and Longstaff (1993) analysed the S&P 100 index option bid-ask spreads across exercise prices and maturities. Market-making costs and option trading activity were proved to be the influential factors of cross-sectional variations of these spreads. Mayhew *et al.* (1999) supported that option order flow is closely related to the characteristics of underlying stocks. Option liquidity changes noticeably across diverse underlying equities. In particular, option liquidity increases with stocks that contain higher prices and trading volumes, greater volatilities, and smaller sizes. Kalodera and Schlag (2004) examined the relationship between daily underlying stock market activities and option liquidity and found the crucial factors of transaction-based and order-based option liquidity regarding the trading volume of underlying stocks. It detected that the trading volume of underlying stocks is positively related to transaction-based option liquidity. The negative stock returns are the common determinants of order-based liquidity measures, such as option spread and depth, while stock return volatility increases option depth.

In more recent studies, Cao and Wei (2010) investigated commonality in option market liquidity based on the measures of bid-ask spread, volumes and price effects. Option liquidity commonality becomes stronger when the underlying stock liquidity and volatility are controlled. Additionally, the option liquidity commonality is also closely related to the movements of underlying stocks. On the one hand, the response of option liquidity is asymmetrical to upward and downward market movements. On the other hand, calls and puts move in the same direction, but to different extents.

Furthermore, Wei and Zheng (2010) investigated the effects of trading activities on individual equity option liquidity based on the proportional bid-ask spread. There are three empirical findings present in their paper. Firstly, option return volatility is more appropriate used for explaining the option spread variation than stock return volatility and option volume. Secondly, due to a maturity-substitution effect, increased option trading activities cause bid-ask spreads of short-term options to be smaller, thereby increasing the option market liquidity. Thirdly, because of the moneyness-substitution effect, increased stock return volatility shifts trading from in-the-money options to out-of-the-money options, and thus narrows the out-of-the-money option spread.

Although these studies showed a close relationship between underlying stock trading activities and option liquidity, they did not explore the reasons why underlying stock trading activities have significant effects on option liquidity. Not mentioning the effects of underlying stock liquidity on option liquidity in these articles compromises the understanding of these aspects of the academic field. The following part will bridge this gap in the option liquidity literature.

The underlying stocks are extensively used as hedging instruments by option traders to reduce risks. Theoretically, Black and Scholes (1973) assumed that underlying stocks are traded continuously without any transaction costs in a frictionless market. As a result, traders continuously rebalance their position in the underlying stocks to replicate options. In other words, option market makers are more competent to eliminate inventory risks completely by hedging underlying stocks. In practice, it is unlikely that perfect replication will exist if transaction costs and discrete trading are considered.

In order to improve Black and Scholes (1973) option pricing models, some studies tried to investigate option revision strategies affected by both discrete trading and trading costs. Leland (1985) introduced the transaction costs and trading frequency into Black-Scholes model by simply adjusting volatility. In the presence of transaction costs, the net stock purchasing price is higher while the net stock selling price is lower. The stock price changes, modelled as the volatility of stock price in the Black-Scholes model, seem to put bounds on option prices. However, the effects of transaction costs on option pricing will be eliminated when the revision is continuous. Discrete revision causes estimated option price errors. This error does not tend to approach zero as presumed when there are transactions costs and more frequent revisions in markets. By contrast, hedging errors have no correlation with the market and tend to be zero when there is more frequent revision. Similarly, Boyle and Vorst (1992) also discussed option replication in the theoretical framework of discrete-time trading with transaction costs. Their article extended the Cox-Ross-Rubinstein binomial option pricing model with proportional transaction costs. Replicating portfolios are constructed per trading time interval. Option prices are presented for parameter values. Derived from the Black-Scholes model with transaction costs, their research provided a new estimated price, which is more accurate for reasonable parameter values.

Furthermore, underlying stock bid-ask spread and discrete trading generate the cost differences of replicating a long option position and a short option position (Leland, 1985; Boyle and Vorst, 1992). On the one hand, the option price sensitivity to stock price increases with the increasing stock price (i.e., delta). Investors are required by replication to purchase more stock shares at the ask price. On the other hand, if there is a fall in stock price, a stock is sold at the bid price to maintain a delta neutral position. Replicating costs of a long call option in the market with transaction costs and discrete trading will be higher than those in a frictionless market. Adopting these logical reasonings, the revenue from replicating a short call option in the market with transaction costs and discrete trading will be less than that in a frictionless market. Thus, these articles implied a positive relation between option bid-ask spread and underlying stock spread.

In addition, the inability to hedging rebalance continuously in option markets affects option bid-ask spread variations (Jameson and Wilhelm, 1992). Stochastic hedge ratio reflects discrete hedge rebalancing. Option dealers increase this stochastic risk exposure through their delta neutral trading. No doubt that market makers engage actively to pursue a hedge portfolio that is instantaneously riskless, but they always fail. The failure of hedge rebalancing exposes market makers to face underlying stock risk. Thus, market makers can diversify risks, but always face the discrete rebalancing risks in option markets.

2) The Effects of Hedging Costs of Option Liquidity

As hedging is important to derivative markets, the hedging failure forces option dealers to bear hedge costs. From a theoretical perspective, hedging costs are the determinants of the option spreads as well as other costs of market making. In other words, hedging costs are the important drivers of the liquidity of derivatives. These costs consist of initial hedging costs and rebalancing costs. Initial hedging costs are 'the cost of setting up and liquidating the initial delta neutral position' and rebalancing costs are 'the costs of rebalancing the portfolio to maintain the delta neutral position' (Kaul *et al*., 2004).

Some articles investigated the effects of each type of costs in option bid-ask spreads. For instance, Kaul *et al.* (2004) focused on strategic trading by informed option investors. This article performed ordinary least squares (OLS) regression and ordered probit models to analyse the influence of strategic trading by informed traders on option spreads. The empirical results showed that because of options hedging activities conducted by market makers, option spreads are affected by the spreads of underlying stocks. The role of initial hedging costs in the spreads of at-the-money or in-the-money options is more significant than that in out-of-the-money option spreads. Rebalancing costs relative to hedging are less than estimated values. This is because option hedgers hold their positions in a short time. Additionally, the adverse selection component embedded in the bid-ask spread of underlying stocks traded has significant explanatory power of option spread. The highest adverse selection costs are for at-the-money, followed by out-of-the-money contracts and out-of-the-money options. These results have a significant implication to the informed option traders and alert that there is a trade-off between leverage and transaction costs regarding option money-ness during trading strategy development.

Based on the study of Kaul *et al.* (2004), Petrella (2006) further analysed the important influential factors of bid-ask spread in option markets. It developed a model incorporating option market-making costs and a reservation bid-ask spread and tested this model on covered warrants, which are option-like securities. In their findings, initial hedging costs and rebalancing costs were proved to be the main contributing factor of option bid-ask spread. What is more, it found the relationship between options and underlying stocks. An option spread is positively related to the underlying stock spread. The reservation bid-ask spread, measured by the option delta and underlying stock tick, also explains a large fraction of the option bid-ask spread. Therefore, their paper not only proved the role of hedging costs in the option spreads, but also provided evidence of the link between underlying stock and option spreads.

3) The Role of Inventory Risk in Liquidity Spillover from Stock Market to Option Market

A large volume of articles concentrated on the effects of hedging costs of option spreads; however, the previous article seldom investigated how market makers' inventory positions affect hedging costs and hence influence option spreads. As the need for inventory risk management contributes to hedging costs, inventory positions of market makers are closely related to these hedging costs. In order to measure inventory costs directly and then examine how the changes of inventory affect hedging costs, Wu *et al.* (2014) firstly considered hedging costs and inventory changes together. The focus of this article was also on the link between bid-ask spreads of options and delta-neutral hedge costs. It found that the role of rebalancing costs is more important than initial hedging costs in option spreads. In addition, rebalancing costs are divided into two sources, 'rebalancing costs due to inventory changes and rebalancing costs due to delta changes. Remarkably, the former costs are more vital than the latter ones in determining the spreads of options.

To a large extent, the level of hedging costs is inversely related to the propensity of option market makers to hedge their underlying stock positions. According to these studies pertained to hedging costs, the study of Li (2016) initially investigated exogenous changes in the liquidity of underlying stocks (the tick size reduction), and then performed a difference-in-difference approach to analyse the effects of underlying stock liquidity on the liquidity of derivative securities, such as options and warrants. The findings indicated that underlying stock spreads decrease considerably after the tick size reduction. Bid-ask spreads of derivatives are negatively related to underlying stock market liquidity and inventory risk. Liquidity changes in the underlying markets spill over to the option market more significantly than the warrant market. This empirical evidence was in line with the derivative hedging theory proposed by Cho and Engle (1999). Bid-ask spreads of derivatives are negatively related to the ability of derivative market makers to hedge underlying stock positions, estimated as underlying stock market liquidity. An increase in underlying market liquidity narrows the bid-ask spreads of derivatives. In addition, liquidity spillover effects from the underlying assets to the derivative securities rely on the propensity to hedge in the underlying markets. A derivative market with the illiquid condition and high inventory risk increases the propensity to hedge in the underlying market, resulting in increased liquidity spillover effects from the underlying market to the derivative market. Therefore, there is a positive effect of underlying stock liquidity on option liquidity. Lowering the tick size of underlying stocks is an efficient method to enhance these effects.

Overall, based on derivative hedging theory and further research of hedging costs, it is reasonable to illustrate that the liquidity of underlying stocks indeed exerts positive effects on option liquidity. Option bid-ask spreads are inversely linked to the hedging ability of market-making positions in the underlying market, estimated as the underlying stock liquidity. When there is an increase in underlying market liquidity, bid-ask spreads of derivatives are narrowed and therefore, option liquidity increases. Additionally, liquidity spillover effects from the underlying stocks to options rely on the propensity to hedge in the underlying markets. Inventory carrying risk is the key driving factor of these liquidity spillover effects.

6.2.2 Asymmetric Information Risk

Trading in different venues or across derivative instrument implies that transactions have no discernible association with information. As informed traders exploit their information advantage in alternative markets, they will choose to trade in profitable markets and benefit from their information. These profitable trading venues have profound implications both for the movement of a security's price and related price behaviour. Trading in option markets plays a vital role in predicting the future movement of underlying security markets. Furthermore, when the amount of information is being incorporated into options, their trading process is not redundant. It is because the trading advantage of option traders stems from their ability to obtain information. If informed traders prefer options markets, the trades of options first reflect information. New information is not impounded into the prices of stocks. Considering the option preference and information asymmetry, there is information transmission across stocks and options through the transactions of market participants (Easley *et al.*, 1998).

1) The Preferred Venue for Informed Trading: Option Market

In earlier studies (Black, 1975), an option was regarded as the preferred trading venue for increased leverage opportunities embedded with options. One of the fundamental theories of information transmission across stocks and options is option leverage. Black and Scholes (1973) regarded options as hedging instruments in a frictionless market. Options can be replicated in continuous time when investing in stocks and bonds. Nevertheless, this dramatic replication is negatively affected by the features of the underlying stock process, such as stochastic discontinuities. What is more, this framework did not mention the importance of options volume.

In reality, option transaction costs prevent perfect option replication (Choy and Wei, 2012), owing to the reason that transaction costs embedded into option value causes unbounded costs (Leland, 1985; Whalley, 2011). As the option market is liquid, transaction costs of options are lower than those of stocks and reduce the difficulty to hide the private information of informed investors (Easley *et al*., 1998; Gharghori *et al*., 2017).

Apart from low trading costs, option leverage is another contributor of large option trading volume (Hayunga *et al*., 2012). According to the Black and Scholes model (1973), Black (1975) firstly argued that investors are likely to benefit from high leverage in the option markets and trade on their private information. Additionally, investors can choose to trade options on negative information when the underlying stocks are subjected to the constraints of short sales. The leverage notion of Black (1975) was extended by the studies of Back (1992) and Biais and Hillion (1994). Informed traders prefer options trading to stocks trading. This is because trading in option markets will find increased opportunities for leverage. Thus, option leverage has been a widely recognized theory of this information transmission.

Nevertheless, some theoretical studies held opposite arguments of option informed trading (Wei *et al*., 1997). In Stein (1987), new traders are possible to bring in additional trading noise, resulting in unstable underlying stock markets. Biais and Hillion (1994) indicated that although option trading lowers the likelihood of a market breakdown, it provides more trading strategies available to informed traders, which causes great difficulties to infer information and reduces market efficiency.

By contrast, Easley *et al*. (1998) built upon these earlier theoretical works and supported the information role of option trading volumes. Because of the high leverage and liquid option market, informed traders prefer options to stocks. It performed an asymmetric information model of informed trading in option or stock markets and then investigated conditions under which informed traders choose to trade in options markets. It also developed the Autoregressive Integrated Moving Average (ARIMA) model to examine the predictions of model for the linkage of prices and volumes of stocks and options. The overall empirical evidence showed that option volumes provide information about upcoming stock prices. When option liquidity relatively increases, compared with stock markets, option markets become preferred by informed traders. It supported the hypothesis that option markets are the preferred venue for informed trading.

Moreover, informed investors prefer option markets for other reasons, such as the absence of an up-tick rule, low borrowing rate and margin requirements. The inexistence of the up-tick rule makes it easier to take a short position by trading options than shorting underlying stocks (Choy and Wei, 2012). In comparison with the stock market, option traders are also highly likely to achieve favourable implicit rates of borrowing and profit from the lower margin requirements.

2) The Information Flow between Option markets and Stock Markets

According to the theoretical literature on option informed trading, the recent empirical studies focused particularly on the informational leading role of the options in relevant to the stocks. Both market liquidity is significantly related to this option informational leadership with stocks.

Due to the sequential flow of information, option trading activities lead to stock prices. Chakravarty *et al.* (2004) found that option market price discovery is associated with stock and option trading volume, and spreads, as well as stock volatility. These relationships are in accordance with the theory that informed traders focus on the importance of option leverage and market liquidity. In addition, financial factors, such as option and stock volume, option and stock spreads, and underlying volatility, considerably affect informativeness in option markets. Pan and Poteshman (2006) proved that future stock returns are negatively predicted by the put-call ratios from option volume. This is consistent with the preceding notions that as option trading carries more information than stock trading in the presence of sufficiently high option leverage (Easley *et al.*, 1998), enhanced option leverage is exploited by informed traders in order to maximize profitability. In other words, options are not deemed as redundant securities by agents. Ni *et al.* (2008) showed that option markets are attractive to informed traders, and option volume provides information for future volatility of underlying stocks. Cremers and Weinbaum (2010) indicated that the deviation from put-call parity is informative about the changes in future stock prices. According to the Easley *et al.* (1998) model, the degree of predictability becomes larger with relatively high option liquidity and relatively low stock liquidity, while it is weaker in the condition of low option liquidity and high stock liquidity. Nguyen and Yang (2019) constructed an implied funding liquidity measure based on the absolute difference between implied volatilities from the call and the put options in the U.S. market. They found that implied funding liquidity has significant predictability of future excess market returns and macroeconomic variables. These results indicated that implied funding liquidity conveys forward-looking information about economic development. Overall, options trading activities contain information about the future direction of the underlying stock price. Informed investors are more willing to trade in option markets than in stock markets, especially when options provide both higher leverage and liquidity.

However, most of the discussed papers did not examine cross-sectional influential factors of trading activity in option markets corresponding to that in the underlying stock markets. To fill this gap, Roll *et al*. (2010) firstly examined the influential factors of the option volume relative to the underlying stocks. The relative trading volume in options and stocks (O/S) is calculated as the ratio of total listed options trading and concurrent stock trading. It is closely related to size, the costs of trading, option delta as well as implied volatility. In the empirical evidence of size effects, larger and more visible companies require the higher O/S ratio, and the spread of options is significantly negative. Both the dollar O/S and share O/S show negative value. These results indicated that option market liquidity improves the relative trading volume in options and stocks, whether agents become informed or they consider they are informed. Additionally, the rise of O/S prior to earning announcement causes some traders to imagine they acquire relative information about upcoming events, which reveals that there will be more successful trading on information.

As the relative trading volume in options and stocks (O/S) carries the private information of informed traders, Johnson and So (2012) analysed the relationship between O/S and future underlying return. This ratio not only forecasts directional changes of prices, but also predicts negative cross-sectional association with private information. The companies with low O/S perform better than the market while companies with high O/S perform worse than the market. What is more, the O/S-return relation becomes weaker with high option leverage. The increase of option leverage enlarges option spreads but weakens the O/S-return relation. It is because bid-ask spread acts as switching costs for option traders to avoid short-sale costs. If this spread becomes larger, it will provide negative signals for traders not to switch from stocks to options. Thus, the decreasing number of switching traders weakens the O/S-return relation. In other words, option market liquidity is negatively related to the O/S- return relation.

Different from the relative trading volume in options and stocks (O/S), new measurements of informed options trading are constructed by Lin and Lu (2015), which are Implied volatility (IV) spread, and the Implied volatility (IV) skewness. IV spread is measured as the open interest weighted average of the put and call option implied volatility differences and IV skewness is the implied volatility difference between the OTM put options and the ATM call options on the same stocks. It examined the patterns in options prices before analyst news events. In the results, options trading is predictable to excess stock returns, as informed investors prefer option trading to stock trading on their private information about upcoming analyst events. It supported the analyst-tipping hypothesis that analysts leak information about their future reports to options investors. The predictability will be more pronounced in the more liquid option market, which is consistent with the argument of Easley *et al*. (1998) that the options market is more attractive to informed traders than the stock market if option market liquidity becomes higher.

3) The Role of Information Asymmetry in Liquidity Spillover from Options to Stocks

Mounting evidence showed that informed traders prefer option market, owing to the option market characteristics, such as high leverage, low trading costs, and the inexistence of short-selling constraints (Black, 1975; Manaster and Rendleman, 1982; Back, 1993; Biais and Hillion, 1994; Easley *et al*., 1998; John *et al*., 2003). As informed investors trade ahead on the option markets, the information flow from the option market to the underlying stocks occurs. This flow of information becomes more pronounced when the option is relatively liquid than that of stock, and vice versa (Roll *et al*., 2010; Lin and Lu, 2015).

Arguably, option traders have an informational privilege over stock traders, which implies hedging activities of option traders incurred from adverse-selection risk convey a signal to stock traders about this risk. Huh *et al*. (2015) examined the hedging activities of option market makers (OMMs) responding to adverse-selection risk. Generally, investors with informational privilege trade on this private information across both stock and option markets. In an unintended circumstance, the hedging strategies of OMMs inadvertently serve as a channel for private information. Eventually, these OMMs' hedging activities adjust the trading strategy of these informed investors. Thus, if OMMs use the underlying stocks to hedge their option position against the asymmetric information risk, their hedging activities will influence these markets liquidity and create the liquidity spillover from option markets to stock markets.

According to the empirical findings of Huh *et al*. (2015), the hedging effects have widened both stock and option market spreads. In particular, the spreading in option markets is more significant than that of stock counterparts. When OMMs find available call options and perceive potential threats of informed trading, they will hedge their option positions and eventually face more transaction costs. OMMs are forced to increase the bid-ask spread of options. However, due to short-sale constraints, OMMs find it more difficult to lay off their inventory, and so, they require higher bid-ask spread to compensate for higher risks. Furthermore, the OMMs' hedging activities increase the degree of information asymmetry in the equity market. Stock market makers are forced by the increased informed trading from OMMs to widen stock spreads. Hence, stock and option market spreads are determined by the OMMs' hedging activities.

Regarding the OMMs' perspective, the operation in the option market has a more pronounced hedging effect on spreads than that in stock counterparts. More than that, this hedging effect exhibits in a greater extent when the markers hedge with the underlying asset than with other options. In general speaking, the coexisting of several options will reduce the spreading of the underlying stock. In particular, the more the options available for hedging, the narrower the spread for each other. As suggested by Huh *et al*. (2015), one of the reasons of OMMs hedging their positions is to reduce the adverse-selection risk which is caused by trading with informed traders. If many options can be adopted by informed traders, the information intensity reflected from the market will be diminished and thereby reducing the information content from the OMMs' hedging strategies. Besides these, the options are constructed as a convex payoff structure, so the number of available options is negatively associated with hedge ratios. In short, the increasing number of options available will reduce OMMs' hedging costs and eventually leading the option spreads to become narrower. Yet, it should be reminded that this effect is occasionally not so strong to counteract the overall effect of the hedging activities performed by OMMs.

Due to the presence of informed traders, OMMs will react to hedge his option position. However, these hedging activities could have a counter effect on both stock and option market spreads. More importantly, the OMMs' responses have significant implications for informed traders to opt for their trading strategies. Consistent with empirical results obtained by Huh et al. (2015), the OMMs' hedging activities regarding information asymmetry will generate additional transaction cost and thereby widening the option spreads for compensation. The OMMs' high short-selling costs incur in the stock market not only reflect in the option spreads but only will be enlarged. Consequently, informed traders will realize these OMMs' signals and lead the stock market maker (SMM) to widen the stock spread by exploiting these advantages. Thus, this study not only offers insights into the role of OMMs' trading activities in both market liquidity, but also provides an explanation of option informational spillover effects from options to stocks.

To sum up, according to the theoretical proposal suggested by Biais and Hillon (1994) and Huh *et al*. (2015), OMMs engages in hedging activities in the derivative market actively will send informational signals to underlying equity traders. As a result, these establish an unintended channel to deliver information to the stock market but have an adverse effect. Because of this information asymmetry, more informed trading initiated by these signals will invest in the equity market. To protect them from these adverse-selection risks, equity traders will increase the equity spread for protection from substantial financial loss. However, this will generate a positive feedback loop, thereby enhancing the hedging costs for the derivative traders and the derivative spreads. More than that, the OMMs' hedging activities provide an alternative mechanism to strengthen the linkage between the derivates and equity market liquidity.

4.3 The Option-Induced Demand Mechanism of Cross-Market Liquidity Linkages

In traditional no-arbitrage theory, the price of the derivative is determined independently of investor demand. After the seminal work contributed by Black and Scholes (1973) and Merton (1973), subsequent studies extended their one-factor option pricing models and introduced various parameters to the theory to enhance explanatory power. For instance, several scholars performed multifactor pricing models and conducted relevant tests, such as Wiggins (1987), Heston (1993), Chernov and Ghysels (2000) and Bates (2000). Recent studies concentrated on the nature of option returns (Bondarenko, 2003; Bakshi *et al*, 2003; Jones, 2006) and the factors of option returns (Cao and Huang, 2007). These studies did not emphasize the role of demand in option pricing. As indicated by Bates (2003), the properties of option prices cannot be fully captured by the traditional method and require a new method to price these derivatives, with the expectation that this method connects with 'financial intermediation of the underlying risks by option market-makers' (Bates, 2003). Additionally, the shape of the implied volatility function for index and individual equity options are associated with net buying pressure from public order flow. For example, S&P 500 options' implied volatility changes are dominated by index put option demand, while equity options' implied volatility changes are most deeply influenced by call option demand (Bollen and Whaley, 2004). Therefore, option-induced demand pressure substantially affects option trading.

Based on the extant literature related to the determinants of option pricing, Garleanu *et al.* (2009) put forward a new factor - demand pressures and explores how demand pressures from end-user ('the agents who have a fundamental need for option exposure') influence option prices, which built upon the inventory risk models of Ho and Stoll (1983) and Grossman and Miller (1988). Contrary to the Black-Scholes-Merton option pricing model, there is indeed no perfect option hedge in reality. Hence, if risk-averse financial intermediaries support the end-user demand for options, this demand will affect option pricing. Theoretically, Garleanu *et al.* (2009) established a model in which competitive intermediaries with a risk-averse attitude cannot provide perfect option hedges. Calculated as a function of net end-user demand, equilibrium prices display the pressure of option demand increases the option price, which is in proportion to the variance of the unhedged portion of the option. In similar, these pressures also affect the prices of other options on the same underlying asset in proportion to the covariance of their unhedged portions. Empirically, it used unique datasets to determine the aggregate positions of dealers and end-users. Expensiveness skewness across moneyness has a positive linkage with skewness in end-user demand across moneyness in the time-series analysis, and this demand also positively affects the expensiveness of single-stock options in the cross-sectional analysis.

Based on the demand-based option theory proposed by Garleanu *et al*. (2009), subsequent research focused on the effects of inventory shocks and demand pressure on option prices and illiquidity. For example, Goyenko *et al*. (2015) investigated whether option-induced demand pressure plays a supplementary role in another dimension of the option market, option illiquidity. Existing studies on option hedging were conclusive about whether two hedging costs faced by option market makers, including delta-hedging costs and rebalancing costs, are the important determining factors of equity options spread (Cho and Engle, 1999; Engle and Neri, 2010; De Fontnouvelle *et al.*, 2003; Kaul *et al.*, 2004). Furthermore, Wu *et al.* (2014) showed that rebalancing costs are more important than initial hedging costs in option liquidity, because option hedgers hold their positions in a short time.

Importantly, option traders cannot hedge completely, as evidence by the significant effects of risk premium of holding uncovered option positions on option spread variations (George and Longstaff, 1993). Due to the imperfect option hedge, Goyenko *et al.* (2015) explored the roles of option-induced demand pressure and information asymmetry in option illiquidity. Regarding the option-induced demand pressure, Garleanu *et al.* (2009) performed a theoretical model of inventory risk to show that net end-user demand for options raises option prices in proportion to the variance of the unhedged portion of the option. To put it another way, net demand plays an additive role in the option illiquidity after accounting for hedging costs (Goyenko *et al.*, 2015).

Information asymmetry, proxied as the higher level of the probability of informed trading (PIN) measure in the underlying equities, represents higher adverse selection costs for option traders, thereby increasing stock spreads as in Easley *et al.* (2002). Higher adverse selection costs also force option dealers to widen their quotes (Glosten and Milgrom, 1985). Large positive option bid-ask spread changing implies that the informed trading activities arrive. Based on these theoretical backgrounds, Goyenko *et al.* (2015) performed modelling and showed that hedging costs are the most important part of option spreads. Controlling for hedging costs, both demand pressure and information asymmetry act as additional sources of risk and option market makers eventually increase spreads in response to risk absorption.

Similarly, the significantly positive effects of option-induced demand pressure on equity option illiquidity premia were found in Christoffersen *et al.* (2018). Option effective spreads are measured by taking double the absolute value of the difference between the trade price and the midpoint of the best bid and offer price, divided by the midpoint. These spreads positively influence the expected option return, owing to the reason that market makers require compensation for the risks and market-making costs is reflected on option illiquidity premia. As indicated by Lakonishok *et al.* (2007) and Gârleanu *et al.* (2009), end-users who have net short positions will pressure market makers to hold net long positions in the equity options market. Market makers then adjust bid-ask spreads and require positive returns on a long position in response to net end-user demand pressure. In the cross-sectional analysis, when demand is more unbalanced, and the cost is higher, equity option spread and expected return increase correspondingly. Empirical findings of Christoffersen *et al.* (2018) showed that stock illiquidity, information asymmetry, greater demand imbalances, and hedging costs raise option effective spreads. After controlling for the proxies for market-making risks, effective spreads affect expected returns in equity option markets economically and statistically. These empirical results indicate that apart from measurable market-making costs, effective spreads contain information about inventory holding costs and other non-quantified risks.

In a different perspective of asymmetric information, Kehrle and Puhan (2015) suggested that the large informed option demand results in reduced option market liquidity and lower pricing efficiency. Following an idea ‘options market sidedness’ (OMS), it connects private information obtained by option traders about the underlying stock with their unbalanced demand for options. OMS indicates that option traders possess information about the direction of future stock returns and take advantage of their private information. Consequently, this will cause an imbalance in the excess demand for options between contract types that they are willing to purchase and other contract types. The reasons for this unbalanced demand are mainly rooted in liquidity problem, hedging demand or noise trading. Hence, a high level of informed demand leads to a one-sided options market [46] which is characterized by asymmetric information. Informed investors are more likely to purchase option contract types, such as OTM options, so that they will have the opportunity to take a leveraged position on their information direction. Empirically, it chooses the excess demand in options to capture asymmetric information and proves its predictability of stock returns. Due to options market strategies of trading in excess demand, returns are economically significant. Additionally, excess option demand raises the bid-ask spread of options, which indicates that large informed trading decreases option market liquidity.

Additionally, the first-order effect of inventory risk faced by option market makers is pronounced in determining option prices. Muravyev (2016) divided the price effects of option trades into two components which are inventory risk and information asymmetry. Compare with information asymmetry, inventory risk contributes more to option trade size. To be more specific, inventory risk causes order imbalances in options which affect option prices five times larger than expected. These imbalances also have greater predictability than other predictors of daily option returns. Additionally, these price effects are also found in stock markets. Both effects of information asymmetry and inventory risk on stock prices become larger for those with lower option volumes. What is more, the large inventory risk and asymmetric information components only attribute to 18% of option spread size, and fixed costs explain the remaining 82%. It is in accordance with the finding of decompositions for the stock spread that the fixed costs component explains 88.6% of the stock spread in Huang and Stoll (1997).

The extant literature on demand-based option pricing suggested that demand pressure is an important determinant of prices and illiquidity in option markets. Korn *et al.* (2019) shifted light on the illiquidity transmission from underlying assets to derivatives. Based on the derivative hedge theory (Cho and Engle, 1999), Korn *et al.* (2019) developed a theoretical model in which derivative market makers face an exogenous demand to hedge their positions in the underlying spot market. Spot market trading is at the risks of illiquidity and prices and experiences an

[46] A one-sided market is a market in which market makers only quote either the bid or the ask price.

illiquidity problem. More specifically, this model is established for a market maker with constant absolute risk aversion (CARA) preferences. Futures price in equilibrium is calculated as a function of the futures-induced demand. The sensitivity of futures-induced demand provides a natural measure of illiquidity in the future market. In the theoretical model, spot market illiquidity is one of the determinants of futures market illiquidity. Several factors, such as price risk, liquidity risk, and the market maker's risk aversion, also interact with spot market illiquidity to determine future market illiquidity. Empirical evidence showed that illiquidity in the future market raises illiquidity in the spot market. Even controlling for asymmetric information, this significantly positive relationship remains. Therefore, option-induced demand, which represents market makers' inventory risk, captures the importance of futures illiquidity. Overall, in accordance with the derivative hedge theory in general and the theoretical model of option-induced demand pressure, the positive illiquidity transmission from spot markets to futures implies a complementary relationship between spot and future market illiquidity. Korn *et al.* (2019) provided the direction for future research on illiquidity interaction between underlying assets and derivative securities.

Nevertheless, there is no perfect option hedging in the real trading market. Provided the asymmetric information is controlled, the demand-based option pricing theory indicates that option-induced demand pressure reflects the market markers' inventory risk, the degree of option's illiquidity as well as its price. For instance, the larger demand pressure for options, the lower the price efficiency and market liquidity. More than that, this pressure contributes to the positive illiquidity transmission from underlying assets to derivatives (Kom *et al.,* 2019)

As with the extant literature, after considering the hedging costs, the net demand for an option contract plays an addictive role in the illiquidity interaction between underlying stocks and equity stocks. In the circumstance where derivatives market makers cannot perform the hedging activities fully because of the underlying asset liquidity, they will have a net short position as a result. Due to the high derivative prices, the market makers will increase the underlying assets price and more expensive short position as a form of compensation. Remarkably, the extent of derivate market illiquidity is positively associated with this increasing underlying assets prices pressure (Korn *et al*., 2019). In a different situation, the option traders will be shocked by this illiquidity and is eventually reflected on the option-induced demand pressures. It is because these traders make their decision based on their own private information. Therefore, market makers who suspect information trading tend to aggressively increase stock illiquidity (Goyenko *et al.*, 2015).

6.4 The Summary of Three Mechanisms Regarding Stock and Option Liquidity Linkage

According to the funding theory, hedging theory, and option demand-based theory, we propose three mechanisms regarding the market liquidity interaction between stocks and equity options. For convenience, we summarize the theoretical predictions in the following table:

Liquidity Spillover	Mechanisms Regarding Stock and Equity Option Liquidity Linkage			
	Funding Mechanism	Hedging Mechanism		Option-induced Demand Mechanism
		Inventory Risk	Asymmetric Information	
Stock ⇨ Option	Positive	Positive	N/A	Positive
Stock ⇦ Option	Positive	N/A	Positive	Positive
Stock ⇔ Option	Positive	Positive		Positive

Notes: This table presents three mechanisms regarding the stock and equity option market liquidity linkages. 'Positive' indicates that their positive liquidity spillover effects can be interpreted by each mechanism. 'NA' indicates that there is no clear prediction.

Table 6.1 Three Mechanisms Regarding Stock and Equity Option Liquidity Linkage

In the funding mechanism, as the market declines lower the ease to obtain funding (namely, funding liquidity), investors' ability is limited by tight funding constraints to provide liquidity. A deterioration in funding liquidity reduces market liquidity, which creates market liquidity linkages. The systematic nature of this financial phenomenon is that funding constraints affect market liquidity and asset prices (Brunnermeier and Pedersen, 2009; Hameed *et al.*, 2010). Under the pressures of the decreasing financial intermediaries' collateral values and binding funding constraints in the market downturns, investors are forced to liquidate. As a result, due to funding shocks, multiple asset market liquidity drops together. Therefore, funding liquidity, one of the supply-side factors, plays a vital role in the market liquidity interactions across multiple assets, including underlying stocks and equity options.

There are two parts of the hedging mechanism. Firstly, inventory risk is an important driving factor of the stock-option liquidity spillover effects. When the underlying stock liquidity increases, narrow stock bid-ask spreads enhance the propensity of market makers to hedge their option inventory by using the underlying stocks at a lower cost. This allows them to quote lower option bid-ask spreads in compensation for their hedging costs, resulting in higher option liquidity. It is consistent with the derivative hedging theory of Cho and Engle (1999), which indicated that derivative bid-ask spreads are negatively associated with the derivative market makers' ability to hedge their positions in the underlying market, proxied as the underlying market liquidity. Therefore, as option market makers depend more on underlying stocks to hedge against their inventory risk, the liquidity spillover effects from the underlying stocks to options become more significant (Li, 2016).

Secondly, information asymmetry is a crucial contributor to the option-stock liquidity spillover effects. Based on the theoretical proposal suggested by Biais and Hillon (1994) and Huh et al. (2015), OMMs participate in hedging activities in the derivative market actively will convey informational signals to underlying equity traders. Consequently, these establish an unintended channel to deliver information to the stock market but have an adverse effect. Due to this information asymmetry, more informed trading initiated by these signals invests the equity market. To protect them from these adverse-selection risks, equity traders increase the equity spread for protection from substantial financial loss. However, this generates a positive feedback loop, hence enhancing the hedging costs for the derivative traders and the derivative spreads. More than that, the OMM' hedging activities provide an alternative mechanism to strengthen the linkage between the derivates and equity market liquidity.

In the option induced demand mechanism, accounting for hedging costs, the net demand for an option contract plays an addictive role in the illiquidity interaction between underlying stocks and equity options. On the one hand, underlying asset illiquidity forces derivative market makers not to hedge the exposure fully and thus, they have a net short position. Rising underlying asset prices and the more costly short position requires higher derivative prices as compensation. Under the increasing price pressure, the derivative market illiquidity grows up. The reverse effects hold for the downward trend of derivative values. (Korn *et al.*, 2019). On the other hand, as the major motive of option trading is from private information, shocks to option illiquidity reflect option-induced demand pressures. Market makers who suspect information trading tend to aggressively increase stock illiquidity (Goyenko *et al.*, 2015).

Chapter 7 Empirical Analysis of Stock and Option Market Liquidity Linkages

7.1 Introduction

In the financial markets, it is not unusual to observe that there is a growing use of financial options for investments and risk management purposes. Investors adopt financial options because the option markets allow high leverages (Black, 1972; Easley *et al*., 1998; Chakravarty *et al*., 2004). While previous studies mainly focus on information content of option prices with respect to the underlying stock prices (See, for example, Cremers and Weinbaum, 2010; Cao and Wei, 2010), only few research papers have examined whether trading in option markets reveals any information about the future costs of trading and the provision of liquidity in the underlying stock market.

This paper seeks to fill in this gap and examines the interactions of market liquidity between option and stock markets. The foundation of this paper is built upon the vast volume of theoretical literature dealing with the interplay of option and stock market liquidity. In particular, theories proposed by Cho and Engle (1999) and Li (2016) suggested that option market makers depend on the underlying stocks to hedge their inventory risks. As they argue, option market liquidity is positively influenced by the hedging ability of option market makers or market liquidity of the underlying stocks. Also, the financial theories highlight the potential spillover in liquidity from the option market to the stock markets. Furthermore, the theoretical frameworks (See Biais and Hillon, 1994; Huh *et al*., 2015) show that informed traders prefer to trade first in the option markets to hide their intention. Thus, facing unbalanced positions in the option markets, option dealers rely on the underlying stock markets to hedge, thereby causing option market liquidity to lead the underlying stock market liquidity. For this reason, the following hypothesis will be tested:

Marra (2016) predicts that the illiquidity in the option markets will directly influence liquidity in the underlying stock markets if the asymmetric information exists. Because of higher information risk, the higher hedging costs will force equity option dealers to rebalance their positions into the stock market. As a result, the strategy employed by the equity option dealers will increase the option illiquidity. In addition, the option dealers' hedging activities will deliver a negative signal of higher asymmetric information risk to equity dealer. Then, the equity dealers will enhance the equity illiquidity because of the negative signal. Subsequently, the growing trend in stock illiquidity also further increases option illiquidity.

Also, Gromb and Vayanos (2002) illustrated that arbitrageurs become an intermediary to supply liquidity to other investors. The temporary distortions in prices might be the result of asymmetric information (Marra, 2016). This information asymmetry helps promote arbitrage trading across the two asset markets, which are option and stock markets (that is, capital structure arbitrage). Higher hedge costs, accompanied by a considerable price distortion, will require larger correlated informed arbitrageurs' liquidity demand across these two markets. In this situation, uninformed option and equity dealers will respond in a particular way, by increasing option and equity illiquidity (Foucault *et al*. 2016). Because of a surge in asymmetric information, the possible and convenient option-equity arbitrage (such as large option mispricing and high hedge costs) will increase two market illiquidity.

However, in frictional markets, traders cannot hedge the market exposure fully. After accounting for hedging costs, the net demand for an option contract has an additive effect on the illiquidity transmission between underlying stocks and equity options (Garleanu *et al*., 2009; Goyenko *et al*., 2015; Christoffersen *et.al*, 2018).

On the one hand, underlying asset illiquidity forces derivative market makers not to hedge the exposure fully and thus they have a net short position. Rising underlying asset prices and the more costly short position requires higher derivative prices as compensation. Under the increasing price pressure, the derivative market illiquidity grows up. The reverse effects hold for the downward trend of derivative values. (Korn *et.al*, 2019).

On the other hand, as the major motive of option trading is from private information, shocks to option illiquidity reflect option-induced demand pressures. Market makers who suspect information trading tend to aggressively increase stock illiquidity (Goyenko *et al*., 2015).

Following these key studies, the following hypotheses will be tested:

H_1: Inventory risk is a driving factor of the stock-option liquidity spillover effects.

H_2: Information asymmetry is a driving factor of the stock-option liquidity spillover effects.

Furthermore, funding liquidity is also important to the market liquidity interactions across underlying stocks and equity options. As the market declines reduce the ease of obtaining funding (that is, funding liquidity), the ability of investors is limited by tight funding constraints to provide liquidity. A drop in funding liquidity decreases market liquidity, thereby creating market liquidity linkages. The systematic nature of this financial phenomenon is that funding constraints influence market liquidity and asset prices (Brunnermeier and Pedersen, 2009; Hameed *et al*., 2010). The pressures from the decreasing financial intermediaries' collateral values and binding funding constraints in the market downturns force investors to liquidate. Consequently, because of funding shocks, multiple asset market liquidity declines together. For these reasons, the following hypothesis will be tested:

H_3: Funding liquidity contributes to the stock-option liquidity spillover effects.

It is worth mentioning that there are different degrees of the stock-option liquidity linkages in firms of different sizes. According to Cao and Wei (2010), large-size companies are less susceptible to the risks related to inventory holding and information asymmetry. By contrast, small companies experience more from these two kinds of risks. What is more, large companies not only have sufficient capital to fully absorb liquidity shocks, but also have a higher ability to access financial markets to obtain external funding (Pinkowitz *et al*., 2006; Hameed *et al*., 2010). Therefore, larger companies have more significantly positive stock and option liquidity linkages than smaller companies. For these reasons, the following hypothesis will be tested:

H4: Stock-option liquidity spillover effects become more significant in larger firms.

In order to shed some light on this important issue, this research analyses a large cross section of U.S. stocks and equity options over an extended period. We consider the interactions of option and stock market liquidity in a vector autoregressive system and measure the long-term impact of option liquidity on stock market liquidity, and vice versa. In addition, we examine these interactions at the firm level and assess the firm characteristics that explain the linkages between stock and option market liquidity.

Our study analyses the equity option data collected from Option Metrics over the period from January 12, 2004 and August 31, 2015. This database includes individual option details such as the bid and offer prices, the exercise price, the maturity dates, the option interests as well as the implied volatility obtained by matching the Black and Scholes (1973) and Merton (1973)' formula with the market price. We supplement the option data with the stock market data obtained from the Centre for Security Research (CRSP) over the same period. This database contains the closing bid and ask prices, trading volumes, the number of shares outstanding, and the unique security identification that allows stock market data to be matched with the option data.

The results obtained from this study prove that our research in a concrete way. This paper documents positive linkages between stock and option market liquidity. That is, the higher illiquidity in the option market leads to the higher illiquidity of the underlying stocks and vice versa. That means, one standard deviation increase in option liquidity leads to an increase of 0.065 standard deviation in stock liquidity. Meanwhile, one standard deviation increase in stock liquidity will lead to 0.195 standard deviation rise in option market liquidity. These impacts are permanent and significant. Our study also shows that these magnitudes of the feedback effects vary across firms. We show that the company size, the number of short-selling interests and the probability of informed trade (PIN) measure can explain the cross-sectional variations in the degrees of these interactions effectively. Smaller size firms experience higher linkages between stock and option market liquidity. Meanwhile, a higher probability of information trading or greater short-selling pressure is associated with reductions in the links between stock and option market liquidity.

The research of the joint liquidity dynamics of equity options and equities has implications in several contexts. Firstly, understanding the dynamics of the stock and equity option liquidity could 'provide a useful framework for anticipating, and ultimately preventing, cases where a breakdown in liquidity can escalate to financial market stress or crisis, even in the absence of other significant events.' Secondly, a deeper understanding of the dynamics of liquidity spillover benefits for individual and institutional traders to provide a systematic framework for anticipating, and finally preventing financial market stress or crisis which incurred from liquidity breakdown (Verousis *et al*. 2016a).

The rest of the paper is organized as follows. Section 2 describes data. Section 3 shows empirical methodology. Section 4 explains the expected results and result implications. Section 6 shows the robust checks. The final section will be the conclusion.

7.2 Data

The sources of the data are mainly described in this section. Both of the stock and option datasets are equally important to this study, which are used to measure their liquidity. The sample period covers between January 2004 and August 2015. This paper excludes utilities firms and services firms. To eliminate outliers, this paper detects outliers by determining an interval spanning over the mean plus/minus three or four standard deviations at the firm level. There are two types of asset databases, respectively.

The daily options are all equity options, selected from Option Metrics database, which supplies industry group, option types, daily bid and ask quotes, strike price, trading volume, and option Delta. This research uses the following procedure to prepare the option data for the analysis. This paper deletes observations related with a zero-trading volume and price (Cao and Wei, 2010). It removes abnormal option bid and ask quotes if the bid-ask spread is negative or greater than $5 (Byun and Kim, 2016); To ensure the sample representativeness, it deletes options with a maturity longer than 240 days (Wei and Zheng, 2010). To avoid potential pricing structure issues related to the deep in-the-money and deep out-of-the-money options, options whose moneyness is inside the range of [0.9, 1.1] (Wei and Zheng, 2010). To mitigate the volatility term-structure effect, it discards options with the value of delta smaller than -1 or greater than 1 to account for thin trading.

To keep nonstandard settlement transactions, it removes zero Option Metrics' variable for "settlement flag" (variable name: ss_flag). To ensure the existence of option volume weighted absolute implied volatility spread, it matches each pair of call and put option of the same underlying stock with the same strike price and maturity and remove non-pair call and put options.

Stocks are sourced from the Centre for Security Research (CRSP) database in the recent periods from January 2004 and August 2015, which contains shares outstanding, prices, bid and ask prices. The stock data is screened in the following way. This paper deletes observations related to a zero-trading volume, shares outstanding and price. It also deletes anomalous stock transaction records if quoted spread (bid-ask) >$5 (Hameed *et al*., 2010).

7.3 Empirical Methodology

This section primarily describes how to measure the stock and option market illiquidity and performs different models to examine their interactions. Following Choy and Wei (2012) and Liu, Zhang *et al.* (2018), this paper uses weekly frequency to study the dynamics of liquidity measures.

The levels of individual liquidity of stocks and options in the US are prone to display a significant degree of collinearity, influenced by common factors among multiple assets. Principal component analysis (PCA) is a fully developed methodology to combine the information embedded in different liquidity measures. A set of components extracted by PCA are deemed as the most vital unrelated source of the variances in liquidity (Verousis *et al*., 2016a).

Before employing PCA, this paper standardizes the series of stocks and options to have zero mean and unit variance (Dunne *et al.*, 2011). Subsequently, it performs PCA to extract the common liquidity factors from individual stock and equity option.

7.3.1 Liquidity Measures

This part presents stock liquidity which measured as the proportional bid-ask spread, Amihud illiquidity ratio.

Stock proportional bid-ask spread: The daily proportional spread of a stock is measured as the bid–ask spread divided by the midpoint between the bid and ask quotes per day (Chordia et al., 2000).

Amihud illiquidity ratio: On the basis of Amihud (2002), this paper defines Amihud illiquidity ratio as the 20-day moving average daily absolute return divided by the trading volume the day before.

This part also shows three option illiquidity proxies, measured as volume-weighted proportional bid-ask spread, and volume-weighted absolute implied volatility spread.

Volume-weighted option proportional bid-ask spread: The proportional spread of an option is measured as the bid–ask spread divided by the midpoint between the bid and ask quotes with the same strike price and maturity (Cao and Wei, 2010). Then this paper takes the sum of the trading volume times the proportional spread and then takes it divided by the total trading volume per day.

Equal-weighted absolute implied volatility spread: Absolute implied volatility spread is the absolute difference between the implied volatilities of the same pairs of call and put options on the same underlying stock with the same strike price and the same expiration date (Rösch *et al*., 2016). This paper, then, takes the sum of the absolute implied volatility spread and then takes it divided by the total trading numbers per day.

7.3.2 Vector Autoregression

Based on previous empirical studies, this study concentrates on the option and stock market liquidity linkage. The weekly first principal components of option and stock liquidity are measured at the market level. Their liquidity interactions will be examined based on the modified vector autoregressive model (VAR model, hereafter). Vector autoregressive model is modified by adding some determinants as the exogenous variables that affect both stock and option market liquidity, such as funding liquidity and mutual fund flow.

There are two advantages of performing a vector autoregressive model. On the one hand, it is not only parsimonious to include both contemporaneous components and lags but also accurately used to predict the future trends based on the consideration of the history of other variables

(Verbeek 2008). On the other hand, endogenous and exogenous variables are not distinguished, and no constraints are required to make sure the identification (Sims, 1980; Canova, 1995).

Based on this model, the dynamic evolution of stock and option market liquidity from their history is described. When these variables are taken into consideration, the VAR model includes two equations. Regarding the effects of market-level variables, an n order VAR model of stocks and option liquidity is written as:

$$SILIQ_{M,t} = \sum_{j=1}^{n} \alpha_{11,j} * SILIQ_{M,t-j} + \sum_{j=1}^{n} \beta_{12,j} * OILIQ_{M,t-j} + \theta_{11,j} * X_{M,t} + \varepsilon_{1m,t};$$

$$OILIQ_{M,t} = \sum_{j=1}^{n} \alpha_{21,j} * SILIQ_{M,t-j} + \sum_{j=1}^{n} \beta_{22,j} * OILIQ_{M,t-j} + \theta_{21,j} * X_{M,t} + \varepsilon_{2m,t};$$

where $SILIQ_{M,t}$ denotes stock market-level liquidity measures in the trading day t; $OILIQ_{M,t}$ denotes option market-level liquidity measures in the trading day t; $X_{M,t-j}$ denotes the exogenous variables at lag j from the trading day t. This model is estimated for each company and at the aggregate market level over the whole sample period.

Wald test is based on the sums of the coefficients of lagged alphas and betas in the VAR models. These test statistics are for the tests that the corresponding sums of coefficients are equal to zero (Chordia *et al*., 2005). The small p-value indicates that the observed test statistic is unlikely under the null hypothesis. Both p-values of Wald-statistics on the sum of the coefficients of lagged alphas and betas are smaller than 1%, so this paper rejects their null hypotheses. In other words, there is illiquidity causality between stock and option markets.

7.3.3 Cross-Sectional Model of Alpha and Beta

There are two cross-sectional regressions in this part. These regressions are used to investigate the effects of firm size, short-selling interest and the probability of information trading on Alpha and Beta in 50 size groups. The option and stock liquidity are estimated as the weekly average of the first principal components of stock and option illiquidity measures in each size quintile. These two regressions are written as

$$Y_{i,t} = Int_{3i} + \theta_{31} * Size_{i,t} + \theta_{32} * Shortint_{i,t} + \theta_{33} * PIN_{i,t} + \varepsilon_{3i,t};$$

where $Y_{i,t}$ is the variable of interest (alpha, beta); $\alpha_{i,t}$ denotes the total estimated coefficients of past stock on contemporaneous option illiquidity from vector autoregressive models for each group; $\beta_{i,t}$ denotes the total estimated coefficients of past option liquidity on contemporaneous stock illiquidity from vector autoregressive models for each group; $Size_{i,t}$ denotes the average of firm size for each group in the sample period; $Shortint_{i,t}$ denotes the average of short-selling interest for each group in the sample period; $PIN_{i,t}$ denotes the average of PIN measure for each group in the sample period.

7.4. Empirical results of Market-Level Stock and Option Illiquidity

There are three parts in this section. The first part presents summary statistics, Pearson correlations, and stationary tests. The second part shows the results of Vector-Autoregressive Models. Before performing Vector-Autoregressive Models, all the variables are all standardized. The third part indicates the cross-section regression results.

7.4.1 Descriptive Statistics

Table 7.1 presents the summary statistics for stock market liquidity, which measures for the sample period of January 2004 to August 2015. In Panel A, the average of all stock proportional bid-ask spread is 0.77, similar to the average spread of medium-size (0.80). Compared with small-size companies, other three company groups have smaller illiquidity in terms of both the mean, the median. The standard deviations in these four groups are around 0.6. Their first order autocorrelation coefficients are high, above 0.6. Controlling for market capitalisation, there is a monotonic decreasing pattern of stock illiquidity from 0.99 to 0.59, when the firm size increases. It coincides with the stylized fact that, at the market level, more stocks are being traded in the larger companies with decreasing stock proportional bid-ask spread.

In Panel B, the average of all Amihud illiquidity ratio is 0.16, which is similar to the average ratio of medium-size companies (0.16). Compared with small-size companies, the other three company groups, which are medium, large and all, have smaller illiquidity in terms of both the mean and the median. The standard deviations in these four groups are around 0.04. Their first order autocorrelation coefficients are high, almost 0.95. Controlling for market capitalisation, there is a monotonic decreasing pattern of stock illiquidity from 0.28 to 0.06 when the firm size increases. It coincides with the stylized fact that, at the market level, more stocks are being traded in the larger companies with decreasing Amihud illiquidity ratio.

Panel A: Summary Statistics of Quoted Bid-Ask Spread

	Small	Medium	Large	All
No. Firms	324	432	323	1079
Mean	0.99	0.80	0.59	0.77
Median	0.85	0.66	0.47	0.64
Std Dev	0.68	0.65	0.53	0.61
Max	12.53	11.64	8.98	10.94
Min	0.44	0.30	0.21	0.31
AC (1)	0.63	0.68	0.70	0.68

Panel B: Summary Statistics of Stock Amihud Liquidity Ratio (Amihud)

	Small	Medium	Large	All
No. Firms	324	432	323	1079
Mean	0.28	0.16	0.06	0.16
Median	0.27	0.15	0.06	0.15
Std Dev	0.07	0.05	0.02	0.04
Max	0.75	0.38	0.13	0.37
Min	0.18	0.09	0.04	0.09
AC (1)	0.95	0.96	0.96	0.95

Note: This table reports the basic descriptive statistics for the quintile version of market-level stock proportional bid-ask spread (sbas) and Amihud illiquidity ratio (Amihud). This paper groups the descriptive statistics by market capitalisation. The proportional spread is 1000 times the bid–ask spread divided by the midpoint between the bid and ask quotes per day. Amihud illiquidity ratio is 10 times the 20-day moving average daily absolute return divided by the trading volume the day before. Firm size equals share price multiplied by the number of shares outstanding. After taking average of daily market capitalisation, this paper takes the logarithms of it. All represents all companies. This table sorts companies into three catalogues Small (0-30%), Medium (30%-70%), Large (70%-100%), based on firm size. This table contains the number of firms, and the mean, median, standard deviation, minimum, maximum and AC (1) for stock illiquidity measures over the entire sample period. AC (1) represents the first order autocorrelation coefficients. The sample period spans from January 2004 to August 2015.

Table 7.1 Summary Statistics of Stock Market Illiquidity

Table 7.2 presents the summary statistics for option market liquidity measures between January 2004 and August 2015. Panel A shows that the average option proportional bid-ask spread is 0.15. The standard deviations in these four groups are around 0.03. Controlling for market capitalisation, this table displays a monotonic decreasing pattern of option averaged spreads from 0.19 to 0.11 when the firm size increases. Almost all the first-order autocorrelation coefficients are higher than 0.4. Therefore, at the market level, more options are being traded in the larger companies, thus decreasing option proportional spread.

Panel B shows that the average of option equal-weighted implied volatility spread is 0.19. Their standard deviations in these four groups are between 0.08 and 0.11. Controlling for market capitalisation, this table displays a monotonic decreasing pattern of option implied volatility spreads from 0.26 to 0.14, as firm size increases. Almost all the first order autocorrelation coefficients are around 0.8. Therefore, at the market level, more options are being traded in the larger companies, thus decreasing option implied volatility spread.

Panel A: Summary Statistics of Option Proportional Spread (obas)

	Small	Medium	Large	All
No. Firms	324	432	323	1079
Mean	0.19	0.17	0.11	0.15
Median	0.19	0.16	0.11	0.15
Std Dev	0.03	0.03	0.03	0.02
Max	0.35	0.29	0.22	0.28
Min	0.13	0.12	0.06	0.10
AC (1)	0.53	0.40	0.63	0.43

Panel B: Summary Statistics of Option Implied Volatility Spread (ivdiff)

	Small	Medium	Large	All
No. Firms	324	432	323	1079
Mean	0.26	0.20	0.14	0.19
Median	0.23	0.17	0.12	0.17
Std Dev	0.11	0.10	0.08	0.09
Max	1.00	0.98	1.37	1.11
Min	0.12	0.10	0.07	0.11
AC (1)	0.83	0.80	0.60	0.78

Note: This table reports the basic descriptive statistics for the quintile version of market-level option proportional bid-ask spread (obas) and implied volatility spread (ivdiff). This paper groups the descriptive statistics by market capitalisation. The proportional spread is the bid–ask spread divided by the midpoint between the bid and ask quotes with the same strike price and maturity. This paper takes the sum of the trading volume times the proportional spread and then takes it divided by the total trading volume per day. Implied volatility spread is the absolute difference between the implied volatilities the same pairs of call and a put option on the same underlying stock with the same strike price and the same expiration date. This paper takes the sum of the absolute implied volatility spread and then takes it divided by the total trading numbers per day. Firm size equals share price multiplied by the number of shares outstanding. Ivdiff is 10 times Implied volatility spread. After taking average of daily market capitalisation, this paper takes the logarithms of it. All represents all companies. This table sorts companies into three catalogues Small (0-30%), Medium (30%-70%), Large (70%-100%), based on firm size. This table contains the number of firms, and the mean, median, standard deviation, minimum, maximum and AC (1) for option illiquidity measures during sample period. AC (1) represents the first order autocorrelation coefficients. The sample period spans from January 2004 to August 2015.

Table 7.2 Summary Statistics of Option Market Illiquidity

Panel A in Table 7.3 reports the Pearson correlations and Augmented Dickey–Fuller tau-test statistics (Tau) results among stock and option illiquidity (Fuller and Battese, 1974), which is based on the market capitalisation. Except for a lower correlation in small companies (0.25), other correlations are more highly significant, higher than 0.35. This finding indicates that stock illiquidity has a close relation with the illiquidity of different types of options. ‘The positive correlation is consistent with the derivative-hedge theory proposed by Cho and Engle (1999)’ (Li, 2016). Controlling for firm size, there is an increasing pattern of stock and option illiquidity correlations as the firm size increases. Cao and Wei (2010) illustrated that companies with larger firm sizes are less susceptible to the risks occurred from inventory holding and information asymmetry, while companies with smaller size suffer more from these two risks. This is the reason why larger companies have more significantly positive stock and option liquidity correlations than smaller companies.

Panel A: Option Correlation Coefficients with Stocks

	Small	Medium	Large	All
CORR	0.25 ***	0.36 ***	0.50 ***	0.42 ***

Panel B: Stock Unit Root Test (Tau)

	Small	Medium	Large	All
SILIQ	-2.50 **	-2.31 **	-2.99 ***	-2.33 **

Panel C: Option Unit Root Test (Tau)

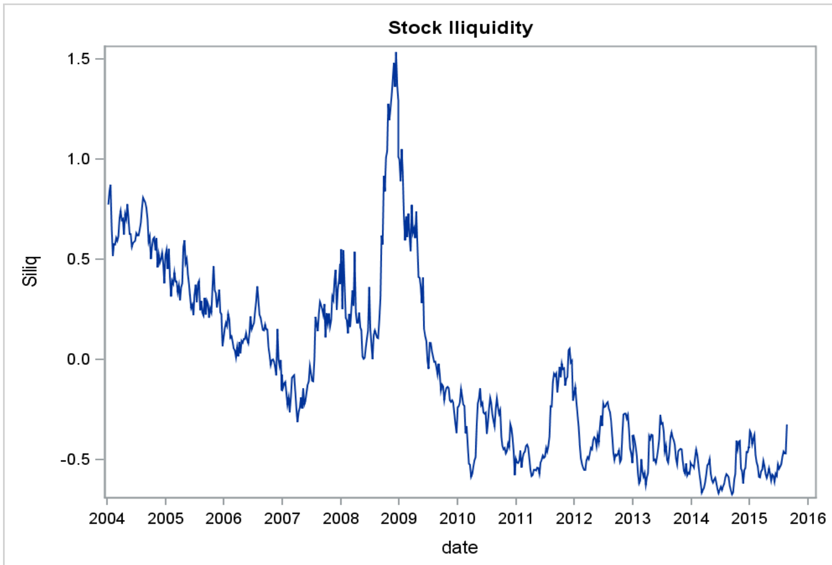
	Small	Medium	Large	All
OILIQ	-10.40 ***	-11.85 ***	-10.97 ***	-11.54 ***

Notes: Panel A of Table 3 presents Pearson correlation coefficients between the first principal components of stock and option illiquidity measures, based on firm size. Panel B and C of table 3 present the zero-mean of ADF tests (Tau Test) for each variable, based on firm size. All represents all companies. This table sorts companies into three catalogues Small (0-30%), Medium (30%-70%), Large (70%-100%), based on firm size. The statistics are presented in the brackets. All the p-values are shown like **Significance at 5% level, ***Significance at 1% level. Unit root test statistics are presented in the brackets. The sample period spans from January 2004 to August 2015.

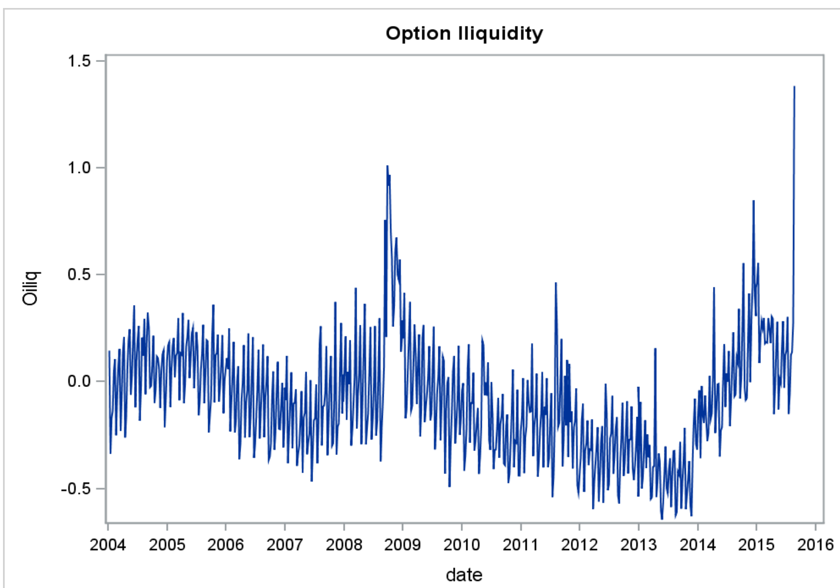
Table 7.3 Pearson Correlation and Unit Root Test at the Market Level

Panel B and C of this table report the test statistics and p-values of the unit root tests for the null hypothesis of stationarity up to 2 lags. This research avoids the risk of obtaining extreme results at the firm level and it tries to avoid the risk of over differentiating variables (Næs *et al*., 2011). The p-values of all stock and option illiquidity variables are smaller than 0.05. They reject the null of a unit root using the ADF test with 2 lags. In short, all liquidity measures selected are stationary series, which means direct analysis based on stock and option liquidity data is reasonable.

Figure 1 plots the time series of the stock market liquidity measure, OILIQ, in Panel A, and of the option market illiquidity measure, OILIQ, in Panel B. Both measures are computed as the first principal components of option and stock liquidity measures. In Panel A, there was a downward trend between -0.16 and 0.87 before 2007. Stock illiquidity began to rise gently to the top of 1.05 in 2009 and then decline sharply from 2009 to 2010. In the last five years, stock illiquidity is much lower than before, but stable within -0.67 and 0.05. In Panel B, despite certain strikes, option illiquidity is stable between -0.65 and 1.38 for the whole period. In particular, there are two top points in 2009 and 2015, above 1.



(a)



(b)

Figure 7.1 The Time Series of Stock and Option Market Liquidity Measures

Figure 7.1: This Figure plots the time series of the weekly first principal component of stock and option market liquidity measures, SILIQ, in Panel A, and of the first principal component of the option market illiquidity measure, OILIQ, in Panel B. The sample period spans from January 2004 to August 2015.

7.4.2 Liquidity dynamics at the market level

This part of the analysis relates to the liquidity spillover effects between stock and option markets. Panel A in Table 7.4 reports the control variables estimated from Vector Autoregressive models. There are two controlled variables in VAR models, which are funding liquidity and mutual fund.

Panel A: Control Variables of Vector Autoregressive Model

	$OILIQ_{M,t}$	$SILIQ_{M,t}$
Ted Spread	0.002 (0.15)	0.03 (6.55) ***
Mutual Fund Flow	0.06 (3.36) ***	-0.03 (-5.27) ***

Panel B: Alpha and Beta of Vector Autoregressive Model

Alpha	0.20 (19.31) ***
Beta	0.06 (20.66) ***

Notes: Panel A of table 4 presents the control variables estimated from the Vector Autoregressive regression of the first principal components of stock and option illiquidity measures at the market level. TED spread is estimated as the difference between the 3-month LIBOR and the 3-month U.S. The quarterly mutual fund flow data come from The Financial Accounts of the United States. Then this quarterly data is divided by 60(=20*3) for use in daily data. The t-test results and corresponding p-values of intercepts and control variables in these rows. T-statistics are presented in the brackets. Panel B shows Alpha and Beta estimated from the Vector Autoregressive regressions. Alpha refers to the sum of estimated coefficients of past stock illiquidity on contemporaneous option illiquidity and Beta refers to the sum of estimated coefficients of past option illiquidity on contemporaneous stock illiquidity from vector autoregressive models. The Wald-test results and corresponding p-values of past stock and option illiquidity in these two rows. Wald-statistics are presented in the brackets. All the p-values in these three panels are shown like *Significance at 10% level, **Significance at 5% level, ***Significance at 1% level. The sample period spans from January 2004 to August 2015.

Table 7.4 Vector Autoregressive Model at the Market Level

Funding liquidity is the liquidity supply in both stock and option markets. Suggested by leading articles of Hameed *et al*. (2010), Boyson *et al.* (2010) and Liu *et al*. (2018), TED spread is a proxy for the level of funding liquidity that is estimated as the difference between the 3-month LIBOR and the 3-month U.S. Treasury bill rate. Due to the mutual funds is functioned to supply liquidity to market participants, mutual fund managers are concerned about liquidity (Huang, 2015). The quarterly mutual fund flow data comes from the *Financial Accounts of the United States* and is provided by the Federal Reserve Bank of St. Louis.

Firstly, the effect of funding liquidity on stock illiquidity is significantly positive (0.03). It implies that an increase in funding liquidity enlarges stock illiquidity and then lowers the stock illiquidity spillover to options. Besides this, the effect of funding liquidity on option illiquidity is insignificantly positive (0.002). It implies that an increase in funding liquidity marginally enlarges option illiquidity and then slightly lowers the option illiquidity spillover to stocks. Overall, an increase in funding liquidity lowers their interactions.

Banks raise the interest rate on unsecured loans and push up the LIBOR Rate in the uncertain market. Both credit risk and flight-to-quality channels generate a positive linkage between Ted spread and funding liquidity (Boudt *et al*., 2017). Brunnermeier and Pedersen (2009) indicated that there is an unstable spiral between stock market liquidity and margin loan. Traders with heightened financial constraints are forced to take on positions, especially those with large capital requirements. There is also a similar situation in option market. This is the reason why decreasing financing liquidity reduces cross-market trading activities (Wang *et al*., 2018).

Secondly, mutual fund flow is significantly positive to option illiquidity (0.06), but significantly negative to stock illiquidity (-0.03). Option illiquidity responds more to mutual fund flow. For example, the extreme mutual fund outflow, namely, fire sales, impairs the stock price informativeness. In the model of Honkanen and Sschmidt (2018), mutual fund fire sales cause a large supply shock, which increase the market uncertainty. Investors are reluctant to withdraw their liquidity from economically related peer companies. There is a liquidity dry-up around the fire sale. Information spillover is a driving factor of stock liquidity spillover. Therefore, when mutual fund flow decreases, stock illiquidity increases at the same time. In the uncertainty market, some informational traders transmit from risky stock market to option market, thereby decreasing option illiquidity.

To sum up, past option and stock illiquidity are positive to contemporaneous themselves and with each other. Funding liquidity positively affects stock and option illiquidity. However, mutual fund flow positively affects option illiquidity, but negatively affects stock illiquidity.

Panel B in Table 7.4 reports the Alpha and Beta estimated from Vector Autoregressive models of market-level stock and option illiquidity. Alpha refers to the sum of coefficients of past firm-level stock illiquidity on contemporaneous option illiquidity and Beta refers to the sum of coefficients of past firm-level option illiquidity on contemporaneous stock illiquidity.

For all the firms, the parameter coefficients of past option and stock illiquidity on their contemporaneous own illiquidity are 0.55 and 0.89. The value of 0.55 implies that if past option illiquidity increases by 0.27 % (the standard deviation in option illiquidity), then contemporaneous option illiquidity increases by 0.27% ×0.55= 0.15% standard deviations. The value of 0.89 implies that if past stock illiquidity increases by 0.46% (the standard deviation in stock illiquidity), then contemporaneous stock illiquidity increases by approximately 0.41% standard deviations. Therefore, past stock and option illiquidity have positive effects on their contemporaneous illiquidity.

From the perspectives of illiquidity spillover across equities and equity options, Alpha is 0.20 and Beta is 0.06. Alpha indicates that if past stock illiquidity increases by 0.46%, then contemporaneous option illiquidity increases by approximately 0.09% standard deviations. Besides this, Beta indicates that if past option illiquidity increases by 0.27% (the standard deviation in option illiquidity), then contemporaneous stock illiquidity increases by approximately 0.02% standard deviations. Thus, stock and option market illiquidity are also positively linked with each other.

Additionally, for each regression, this research performs Wald tests for independent variables (past stock and option illiquidity), testing whether these coefficients on the sub-models are jointly equal to zero (Kaeck *et al*., 2017). For all the regressions, these p-values of the joint tests for the past illiquidity are all below 0.05, suggesting that all the effects of past stock (or option) illiquidity on the contemporaneous stock (or option) illiquidity differ significantly.

After performing VAR models, the impulse response functions (IRF, therefore) show how the stock and option market liquidity react to a one standard deviation of one of the two respective shocks through time. Figure 2 present the accumulated IRFs for stock and option market liquidity. The point estimates are within the range of two standard errors above and two below the mean (±2 Std Dev mark the points within which 95% of the observations lie). The results show clear evidence of these two-market liquidity transmissions. More specifically, stock liquidity is positively influenced by a one standard deviation option liquidity shock upon impact. As time passes away, the stock liquidity continues to be positively affected by this one-time shock, and vice versa.

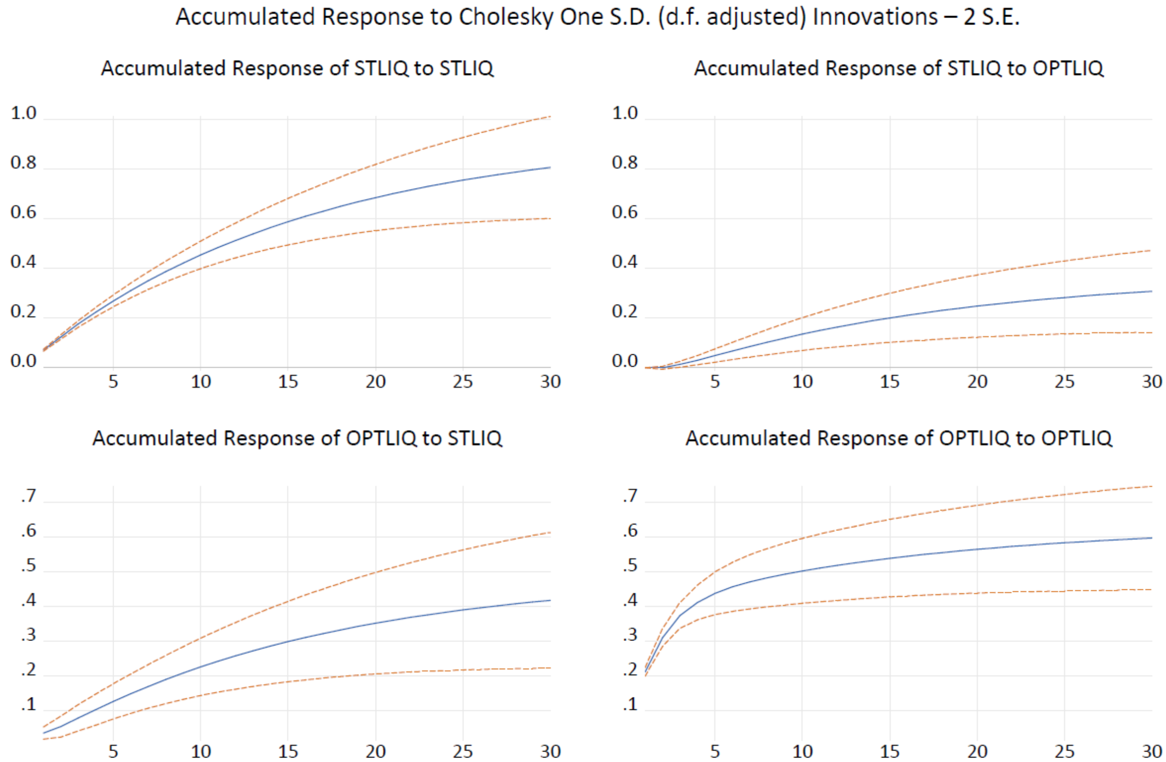


Figure 7.2 The Accumulative Impulse Response Functions

Note: The figure 7.2 shows the accumulative impulse response functions from January 2004 to August 2015. The left panels show the accumulative impulse response functions of stock and option liquidity to a permanent one percent point shock to the stock liquidity, and the right panels show the accumulative impulse response function of stock and option liquidity to a permanent one percent point shock to the option liquidity in the market-level models which incorporates market index, such as TED date and mutual fund rate at the same time. The horizon axis shows the period after the shock. The vertical axis shows the cumulative response. The blue line is the point estimate while the red lines are the bootstrapped 2 standard deviation confidence bands for the model (±2 Std Dev mark the points within which 95% of the observations lie).

7.4.3 Stock and option market liquidity dynamics at the firm and portfolio levels

From a spillover perspective, this research emphasizes the interconnectedness of the own variables with other variables, excluding the explanatory power of past own variables. The total sample period of Panel A is between 2004 and 2015.

In Table 7.5, Alpha refers to the sum of coefficients of past firm-level stock illiquidity on contemporaneous option illiquidity. It presents the summary statistics for Alpha, based on market capitalisation. Alpha remains positive. For all the firms, the average of Alpha equals to 0.08 and its standard deviation is 0.14. Besides this, Alpha shows a decreasing trend in terms of the mean from 0.09 to 0.08 when firm size increases. Their standard deviations are all smaller than 0.15. Thus, the positive effects of past stock illiquidity on contemporaneous option illiquidity are more significant in the small-size companies than medium- and large- size companies.

Size Group	Small	Medium	Large	All
No. Firms	324	432	323	1079
Alpha	0.09 (0.15)	0.07 (0.15)	0.08 (0.13)	0.08 (0.14)
Beta	0.032 (0.07)	0.02 (0.07)	0.027 (0.07)	0.03 (0.07)
Size	14.66 (0.17)	15.41 (0.30)	16.93 (0.77)	15.64 (1.01)
Short-selling Interest	-0.90 (0.60)	-1.24 (0.55)	-1.62 (0.45)	-1.25 (0.61)
PIN	0.11 (0.03)	0.10 (0.03)	0.07 (0.03)	0.09 (0.03)

Note: This table reports the coefficients and their standard deviations (in brackets) of Alpha, Beta, firm size, short-selling interest and PIN measure across all the firms in the sample. Alpha refers to the sum of estimated coefficients of past stock illiquidity on contemporaneous option illiquidity and Beta refers to the sum of estimated coefficients of past option illiquidity on contemporaneous stock illiquidity from vector autoregressive models. Firm size equals the log of daily share price multiplied by the number of shares outstanding for each firm. Then this paper takes average of daily firm size for each firm. Short-selling interest is defined as the log of the ratio of the number of shares short to monthly trading volume. Then this paper takes average of monthly short-selling interest for each firm. The database of annual PIN measure is available at *http://scholar.rhsmith.umd.edu/sbrown/pin-data?destination=node/998*. All represents all firms. This table contains the number of firms, and the mean and standard deviation, for Alpha, Beta, firm size, short-selling interest and PIN measure over the entire sample period. The statistics are presented in the brackets. All the p-values are shown like **Significance at 5% level and ***Significance at 1% level. This table sorts companies into three catalogues Small (0-30%), Medium (30%-70%), Large (70%-100%), based on firm size. The sample period of pin measure spans from January 2004 to August 2015 and the sample period of other variables spans from January 2004 to December 2010.

Table 7.5 Summary Statistics of Firm-Level Characteristics

In this table, Beta refers to the sum of coefficients of past firm-level option illiquidity on contemporaneous stock illiquidity. For all the firms, the average of Beta is 0.03 and its standard deviation is 0.07. Based on market capitalisation, the past option illiquidity is decreasingly positive to contemporaneous stock illiquidity. Beta also has a decreasing trend from 0.032 to 0.027. Their standard deviations are all nearly 0.07. It indicates that past option illiquidity has less significant positive effects on contemporaneous stock illiquidity with the increase of firm size.

This table also shows descriptive statistics of firm size, short interest and pin measure. Firm size is based on the number of shares outstanding and the daily stock prices. It is the logarithm function of firm size. Then the firm size is averaged over the sample period and this average is used to form size quintiles (Cao and Wei, 2010). Also, short-selling interest is defined as the logarithm of the ratio of the number of shares short to the monthly trading volume (Ackert and Athanassakos, 2005). Then the short-selling interest is averaged over the sample period and this average is also used to form size quintiles. Additionally, the database of annual PIN measure from January 2004 to December 2010 is available at *http://scholar.rhsmith.umd.edu/sbrown/pin-data?destination=node/998.*

For all the firms, the average of firm size is 15.64 and its standard deviation is 1.01. It arises from 14.66 to 16.93. Most of the standard deviations are all within 1. Furthermore, the average of short-selling interest is -1.25 and its standard deviation is 0.61. It declines from -0.90 to -1.62 when firm size increases. Their standard deviations are within 0.6. In addition, the average of PIN measure is 0.09 and its standard deviation is 0.03. It declines from 0.11 to 0.07 when firm size increases. Their standard deviations are within 0.03.

Then this paper examines Alpha, Beta and their determinants at the portfolio level. Their determinants are firm size, short-selling interests and pin measure. Concerning firm size, it is based on the log transformation of the number of shares outstanding and the daily stock prices (Cao and Wei, 2010). The stock and option liquidity interactions are the results of these two kinds of risks via funding channel and hedging and arbitrage channel. The larger size companies are less susceptible to these kinds of risks, while smaller size companies suffer more in these risks. This is reason why larger size companies exhibit lower levels of linkages between stock and option market liquidity.

As proposed by Ackert and Athanassakos (2005), the short-selling interest is defined as the log transformation of the ratio of the number of shares short to monthly trading volume. The buy (sell) trading decisions are fully contained in trading volume and short sales, but not reflect in the number of shares outstanding. Short-selling pressures increase information uncertainty, and thus decrease market liquidity interactions across stocks and equity options.

Regarding to the probability of informed trade (PIN) measure, proposed by Brown and Hillegeist (2007), it presents the level of information asymmetry in the stock markets. Higher PIN measure indicates the higher information asymmetric risk and vice versa. Also, information trading is closely related to option trading (Lu and Lin, 2015; Rösch *et al*., 2017). This relationship arises when informed traders are willing to use the options to trade on their information advantage. It is rational to analyse the illiquidity linkage in spot and derivative markets and their determinants in this research.

The cross-sectional regressions explore the effect of firm size, short-selling interest and pin measure on Alpha and Beta across 50 size quintiles in Table 7.6. After taking average of daily stock and option illiquidity in each size quintile, this paper performs Vector-Autoregressive regressions to capture Alpha and Beta. Furthermore, it also takes the average of companies' firm sizes, short-selling interests and PIN measures in each size quintile. According to R-square, they are all positive, which are around 0.2. There is an explanatory power in these regressions.

Variable	Alpha	Alpha	Beta	Beta
Column	(1)	(2)	(3)	(4)
Intercept	0.76 (2.51) **	2.47 (3.26) ***	0.43 (5.01) ***	1.78 (4.63) ***
Firm Size	-0.06 (-2.35) **	-0.13 (-3.09) ***	-0.03 (-4.27) ***	-0.09 (-4.37) ***
Short-Selling Interest	-0.26 (-3.12) ***	-0.08 (-1.33)	-0.09 (-3.88) ***	-0.06 (-1.98) **
PIN	-	-4.35 (-2.15) ***	-	-3.61 (-3.5) ***
R-square	0.19	0.21	0.28	0.31

Notes: Table 6 presents the cross-sectional regression of Alpha and Beta across 50 size quintiles. After taking average of the weekly first principal components of stock and option illiquidity measures in each size quintile, this paper performs Vector-Autoregressive regressions to capture Alpha and Beta. Furthermore, it also takes average of companies' firm sizes, short-selling interests and PIN measures in each size quintile. T-statistics and R-squared are presented in the brackets. All the p-values are shown like *Significance at 10% level, **Significance at 5% level, ***Significance at 1% level. In the first (1) and third (3) columns, the sample period spans from January 2004 to August 2015. In the second (2) and fourth (4) columns, the sample period spans from January 2004 to December 2010.

Table 7.6 Cross-Sectional Regression of Alpha and Beta

In the first (1) and third (3) columns, the sample period spans from January 2004 to August 2015. Regarding the intercepts in these two sub-regressions, they are all positive, which are 0.76 and 0.43. These positive intercepts show that there is an increasing trend in Alpha and Beta. As a result, this also prove that there is a strengthening interconnectedness between stock and option illiquidity with the increase of firm size.

In the first (1) column, the results of the sub-regression of Alpha show that the coefficients of firm size on Alpha are negative and highly significant at the confidence level (-0.06). This indicates that at the firm level, an increase in firm size is associated with 0.06 unit of decrease in Alpha. The effects of past stock illiquidity are less significant on the contemporaneous option illiquidity in the larger size companies. In addition, short-selling interest is also significantly negative relative to Alpha. It implies that at the firm level, an increase in short-selling interest decreases by 0.26 units in Alpha. The effects of past stock illiquidity are much less significant on the contemporaneous option illiquidity in the companies with higher short interest risk. Overall, both firm size and short-selling interest are negative to Alpha.

In the third (3) column, the sub-regression of Beta illustrates that the coefficients of firm size and short-selling interest on Beta are negative and highly significant at the confidence level. The larger effect of short-selling interests suggests that Beta is more sensitive to them than firm size.

An increase in firm size is associated with 0.03 unit decrease in Beta. Also, an increase in short-selling interest decreases by 0.09 units in Beta. These results imply that the effects of past option illiquidity are less significant on the contemporaneous stock illiquidity when firm size is larger, and short-selling interest risk is higher.

In the second (2) and fourth (4) columns, the sample period spans from January 2004 to December 2010. About the intercepts in these two sub-regressions, they are all positive, which are 2.47 and 1.78. These positive intercepts show that there is an increasing trend in Alpha and Beta. There is a strengthening interconnectedness of between stock and option illiquidity with the increase of firm size.

In the second (2) column, the results of the sub-regression of Alpha show that the coefficients of firm size on Alpha are negative and highly significant (-0.13) at the confidence level. This indicates that at the firm level, an increase in firm size is associated with 0.13 unit of decrease in Alpha. The effects of past stock illiquidity are less significant on the contemporaneous option illiquidity in the larger size companies. In addition, short-selling interest is also significantly negative to Alpha. It implies that at the firm level, an increase in short-selling interest decreases by 0.08 units in Alpha. The effects of past stock illiquidity are much less significant on the contemporaneous option illiquidity in the companies with higher short interest risk. Furthermore, the PIN measure is also significantly negative to Alpha. It shows that at the firm level, an increase in PIN measure decreases by 4.35 units in Alpha. The effects of past stock illiquidity are much less significant on the contemporaneous option illiquidity in the companies with higher information asymmetric risk. Overall, firm size, short-selling interest and PIN measure are negative to Alpha.

In the fourth (4) column, the sub-regression of Beta illustrates that the coefficients of firm size, short-selling interest and PIN measure on Beta are negative and highly significant at the confidence level. The larger effect of the PIN measure suggests that Beta is more sensitive to it rather than firm size. An increase in firm size is associated with 0.09 unit decrease in Beta. Also, an increase in short-selling interest decreases by 0.06 units in Beta. Additionally, an increase in PIN measure decreases by 3.61 units in Beta. These results imply that the effects of past option illiquidity are less significant on the contemporaneous stock illiquidity when firm size is larger, short-selling interest and information asymmetric risk are higher.

In summary, the cross-sectional regressions with 50 size quintiles are convinced to show the close relationship between Alpha and Beta. Firm size, short-selling interest and PIN measure are all negative to Alpha and Beta.

7.5. Robustness Checks

This part of the analysis relates to the liquidity spillover effects in stock and at-the-money option markets. It focuses only on at-the-money (ATM) contracts with a spot-to-strike ratio S/K between 0.95 and 1.05. In addition, the ATM option standard deviation is 0.29 and the relevant stock spread deviation is 0.46. Furthermore, the zero-means of ADF test statistics are -2.32 in stock illiquidity and -13.24 in option illiquidity. Their p-values are smaller than 0.05, indicating that these two liquidity measures are stationary series.

7.5.1 Vector-Autoregressive Models and Accumulated Impulse Response Functions at the Market Level

This part of the analysis relates to the liquidity spillover effects between stock and ATM option markets. Panel A in Table 8.7 reports the control variables estimated from Vector Autoregressive models.

There are two controlled variables in VAR models, which are funding liquidity and mutual fund. Firstly, the effect of funding liquidity on stock illiquidity is significantly positive (0.03), but the effect of funding liquidity on option illiquidity is insignificantly negative (0.003). It implies that an increase in funding liquidity considerably enlarges stock illiquidity and slightly enlarges option illiquidity.

Secondly, mutual fund flow is insignificantly positive to ATM option illiquidity (0.08), but significantly negative to stock illiquidity (-0.03). ATM option illiquidity responds more to mutual fund flow. When mutual fund flow increases, ATM option illiquidity becomes higher, but stock illiquidity becomes lower.

Panel A: Control Variables of Vector Autoregressive Model at the Market Level

Variable	$OILIQ_{M,t}$	$SILIQ_{M,t}$
Ted Spread	0.003 (0.19)	0.03 (6.65) ***
Mutual Fund Flow	0.08 (3.93) ***	-0.03 (-5.46) ***

Panel B: Alpha and Beta of Vector Autoregressive Model at the Market Level

Alpha	0.26 (25.45) ***
Beta	0.06 (20.20) ***

Panel C: Cross-Sectional Regression of Alpha and Beta

Variable	Alpha	Alpha	Beta	Beta
Column	(1)	(2)	(3)	(4)
Intercept	0.67 (2.13) **	2.70 (2.62) **	0.49 (3.9) ***	1.86 (4.56) ***
Firm Size	-0.06 (-2.13) **	-0.14 (-2.46) **	-0.04 (-3.49) ***	-0.10 (-4.35) ***
Short Selling Interest	-0.30 (-3.45) ***	-0.11 (-1.37)	-0.12 (-3.46) ***	-0.06 (-1.90) *
PIN	-	-5.24 (-1.90) *	-	-3.63 (-3.32) ***
R-square	0.27	0.12	0.21	0.31

Notes: Panel A of table 8 presents the control variables estimated from the Vector Autoregressive regression of the first principal components of stock and ATM option illiquidity measures at the market level from January 2004 to August 2015. TED spread is estimated as the difference between the 3-month LIBOR and the 3-month U.S. The quarterly mutual fund flow data come from The Financial Accounts of the United States. Then this quarterly data is divided by 60(=20*3) for use in daily data. The t-test results and corresponding p-values of intercepts and control variables in these rows. T-statistics are presented in the brackets. Panel B shows Alpha and Beta estimated from the Vector Autoregressive regression of the first principal components of stock and ATM option illiquidity measures at the market level from January 2004 to August 2015. Alpha refers to the sum of estimated coefficients of past stock illiquidity on contemporaneous ATM option illiquidity and Beta refers to the sum of estimated coefficients of past ATM option illiquidity on contemporaneous stock illiquidity from vector autoregressive models. The Wald-test results and corresponding p-values of past stock and ATM option illiquidity in these two rows. Wald-statistics are presented in the brackets. Panel C presents the cross-sectional regression of Alpha and Beta across 50 size quintiles. After taking average of the weekly first principal components of stock and option illiquidity measures in each size quintile, this paper performs Vector-Autoregressive regressions to capture Alpha and Beta. Furthermore, it also takes average of companies' firm sizes, short-selling interests and PIN measures in each size quintile. In the first (1) and third (3) columns, the sample period spans from January 2004 to August 2015. In the second (2) and fourth (4) columns, the sample period spans from January 2004 to December 2010. T-statistics and R-squared are presented in the brackets. All the p-values are shown like *Significance at 10% level, **Significance at 5% level, ***Significance at 1% level.

Table 7.7 Robustness Check of Stock and ATM Option Illiquidity

In Panel B of Table 7.7, for all the firms, the parameter coefficients of past option and stock illiquidity on their contemporaneous own spreads are 0.44 and 0.89. The value of 0.44 implies that if past ATM option illiquidity increases by 0.29% (the standard deviation in ATM option illiquidity), the contemporaneous ATM option illiquidity will increase by 0.29% ×0.44= 0.13% standard deviations. The value of 0.89 indicates that if past stock illiquidity increases by 0.46%

(the standard deviation in stock illiquidity), contemporaneous stock illiquidity will increase by approximately 0.41% standard deviations. Therefore, past stock and ATM option illiquidity have positive effects on their contemporaneous illiquidity.

In the perspectives of illiquidity spillover across equities and ATM equity options, Alpha is 0.26 and Beta is 0.06. Alpha indicates that if past stock illiquidity increases by 0.46%, the contemporaneous ATM option illiquidity will increase by approximately 0.12% standard deviations. Beta implies that if past ATM option illiquidity increases by 0.29%, contemporaneous stock illiquidity will increase by approximately 0.02% standard deviations. Thus, stock and ATM option market illiquidity are also positively linked with each other.

Also, this research performs Wald tests for independent variables (past stock and ATM option illiquidity), to test whether these coefficients on the sub-models are jointly equal to zero for each regression (Kaeck *et al*., 2017). For all of the regressions, these p-values of the joint tests for the past illiquidity are all below 0.05. This suggests that all the effects of past stock (or ATM option) illiquidity on the contemporaneous stock (or ATM option) illiquidity differ significantly.

To sum up, past ATM option and stock illiquidity are positive to contemporaneous themselves and with each other. Funding liquidity negatively affects ATM option illiquidity, but positively affects stock illiquidity. In contrast, mutual fund flow positively affects ATM option illiquidity, but negatively affects stock illiquidity.

7.5.2 Cross-Sectional Regression

The cross-sectional regressions explore the effect of firm size and short-selling interest on Alpha and Beta across 50 size quintiles in Table 7.7. After taking an average of weekly stock and ATM option illiquidity in each size quintile, this paper performs Vector-Autoregressive regressions to capture Alpha and Beta. Furthermore, it also takes the average of companies' firm sizes and short-selling interests in each size quintile. According to R-square, they are all positive, above 0.1. There is an explanatory power in these regressions.

In the first (1) and third (3) columns, the sample period spans from January 2004 to August 2015. Relate to the intercepts in these two sub-regressions, they are all positive, which are 0.67 and 0.49. The positive intercepts show that there is an increasing trend in Alpha and Beta. The interconnectedness between stock and option illiquidity strengthens.

In the first (1) column, the results of the sub-regression of Alpha show that the coefficients of firm size on Alpha are negative and highly significant (-0.06) at the confidence level. This indicates that at the firm level, an increase in firm size is associated with 0.06 units of decrease in Alpha. The effects of past stock illiquidity are much less significant on the contemporaneous ATM option illiquidity in the larger size companies. In addition, short-selling interest is significantly negative to Alpha. It implies that at the firm level, an increase in short-selling interest decreases by 0.30 unit in Alpha. The effects of past stock illiquidity are less significant on the contemporaneous ATM option illiquidity in the companies with higher short interest risk. Overall, both firm size and short-selling interest are negative to Alpha.

In the third (3) column, the sub-regression of Beta illustrates that the coefficients of firm size and short-selling interest on Beta are negative and highly significant at the confidence level. An increase in firm size is associated with 0.04 units decrease in Beta. Also, an increase in short-selling interest decreases by 0.12 units in Beta. These results imply that the effects of past ATM option illiquidity are much less significant on the contemporaneous stock illiquidity when firm size is larger, and short-selling interest risk is higher.

In the second (2) column, the results of the sub-regression of Alpha show that the coefficients of firm size on Alpha are negative and highly significant (-0.14) at the confidence level. This indicates that at the firm level, an increase in firm size is associated with 0.14 unit of decrease in Alpha. The effects of past stock illiquidity are less significant on the contemporaneous option illiquidity in the larger size companies. In addition, short-selling interest is also significantly negative to Alpha. It implies that at the firm level, an increase in short-selling interest decreases by 0.11 units in Alpha. The effects of past stock illiquidity are much less significant on the contemporaneous option illiquidity in the companies with higher short interest risk. Furthermore, the PIN measure is also significantly negative to Alpha. It shows that at the firm level, an increase in PIN measure decreases by 5.24 units in Alpha. The effects of past stock illiquidity are much less significant on the contemporaneous option illiquidity in the companies with higher information asymmetric risk. Overall, firm size, short-selling interest and PIN measure are negative to Alpha.

In the fourth (4) column, the sub-regression of Beta illustrates that the coefficients of firm size, short-selling interest and the PIN measure on Beta are negative and highly significant. The larger effect of the PIN measure suggests that Beta is more sensitive to it rather than firm size. An increase in firm size is associated with 0.10 unit decrease in Beta. Also, an increase in short-selling interest decreases by 0.06 units in Beta. Additionally, an increase in PIN measure decreases by 3.63 units in Beta. These results imply that the effects of past option illiquidity are less significant on the contemporaneous stock illiquidity when firm size is larger, short-selling interest and information asymmetric risk are higher.

In summary, the robustness check of ATM options and equities are consistent with the results both in both the time-series and cross-sectional regressions. Firm size, short-selling interest and PIN measure have negative effects on Alpha and Beta.

7.6 Conclusion

This article examines time-varying stock and equity option liquidity linkages in the US from January 2004 and August 2015. The literature on their liquidity linkages is consistent with funding theory, derivative hedge theory and option demand-based pricing theory. According to funding theory, funding liquidity is one of the supply-side factors of asset liquidity interactions. Based on derivative hedge theory, OMMs depend more on underlying stocks to hedge against their inventory risk, the liquidity spillover effects from the underlying stocks to options become more significant. What is more, OMMs participate in hedging activities in the derivative market actively will convey informational signals to underlying equity traders, which promote the liquidity spillover effects from options to underlying stocks. Consistence with option demand-based pricing theory, the net demand for an option contract plays an addictive role in the illiquidity interaction between underlying stocks and equity options.

This article presented tests for the four hypotheses developed to provide findings for the empirical research. Table 7.8 presents a summary of the hypothesis testing results and the obtained story, respectively.

Hypothesis	Expected Effect	Result	Obtained Sign
H_1	Information asymmetry is a driving factor of the stock-option liquidity spillover effects.	Supported	+
H_2	Inventory risk is a driving factor of the stock-option liquidity spillover effects.	Supported	+
H_3	Funding liquidity contributes to the stock-option liquidity spillover effects.	Supported	+
H_4	Stock-option liquidity spillover effects become more significant in larger firms.	Supported	+

Note: This table summarizes the hypothesis test results. The columns of variable show hypothesis number, expected results, empirical results and obtained sign. Column of empirical results includes support hypothesis (Supported). Column of obtained sign includes positive effect (+).

Table 7.8 Summary of the Hypothesis Testing Results

The empirical findings highlight the close relationship between equity and equity option liquidity. There are three findings in this research. Firstly, option market illiquidity is positively related to the underlying stock market illiquidity at the market and firm level. Secondly, firm-level liquidity linkage is inversely related with firm size, short-selling interests and PIN measures. Larger size firms and firms with higher short-selling and information asymmetric risks will have less stock and option liquidity interactions. Based on our research, a future study could further investigate the sampling country US with other countries because asset markets in the different countries may affect our research quality outcome in a global context.

Therefore, we closely monitor the interaction between different asset market illiquidity transmission, especially when these markets are characterized by common fundamentals and hedging connections (Marra, 2016). It not only reduces the loss from financial disasters by predicting and even preventing liquidity withdraws, but also develops more complicated risk management tools to control financial resources for market participants. More than that, this research improves both traders and regulators to understand the effects of new trading regulations and changes in (equity option) market structures on introduced on various asset markets.

Table 7.9 Appendix: Variable Definitions

The data sources are CRSP and Option Metrics. The formulas of stock and option liquidity variables are shown as following:

- Stock proportional bid-ask spread:

$$SBAS_{i,t} = \frac{SBid_{i,t} - SAsk_{i,t}}{\frac{SBid_{i,t} + SAsk_{i,t}}{2}}$$

- Amihud illiquidity ratio:

$$AMIHUD_{i,t} = \frac{\sum_{t=1}^{20} \frac{|R_{i,t}|}{SVol_{i,t}}}{20}$$

- Volume weighted option proportional bid-ask spread:

$$OBAS_{j,i,t} = \frac{\sum_{i=1}^{n} \frac{OBid_{j,i,t} - OAsk_{j,i,t}}{\frac{OBid_{j,i,t} + OAsk_{j,i,t}}{2}} * OVol_{j,i,t}}{\sum_{i=1}^{n} OVol_{j,i,t}}$$

- Equal weighted absolute implied volatility spread:

$$IVDIFF_{j,i,t} = \frac{\sum_{i}^{n} \left| IVol_{j,t}^{i,call} - IVol_{j,t}^{i,put} \right|}{n}$$

where $R_{i,t}$ is the return on stock i on trading day t.
$SBid_{i,t}$ is the bid price on stock i on trading day t.
$SAsk_{i,t}$ is the ask price on stock i on trading day t.
$OBid_{j,i,t}$ is the bid price of option j written on stock i on trading day t.
$OAsk_{j,i,t}$ is the ask price of option j written on stock i on trading day t.
$SVol_{i,t}$ is the trading volume on stock i on trading day t.
$OVol_{j,i,t}$ is the trading volume of option j written on stock i on trading day t.
$IVol_{j,t}^{i,call}$ is the implied volatility of call option j written on stock i on trading day t.
$IVol_{j,t}^{i,put}$ is the implied volatility of put option j written on stock i on trading day t.

Chapter 8 Literature Review of Market Liquidity and Stock Price Crash Risk

Stock price crash risk is defined as the negatively skewed distribution of stock returns which reflects asymmetric risk, particularly downside risk (Callen and Fang, 2015a, b). The understanding of crash risk is constructive for portfolio theories and for asset-pricing models (Kim and Zhang, 2016). In common sense, investors have always pursued larger stock returns, but these objectives associated with more significantly negative skewness, which indicates that skewness is a priced factor of risk (Harvey and Siddique, 2000; Conrad *et al.*, 2013). Stock market turmoil, such as financial crisis and covid-19, highlights the role of crash risk in investment decision and policymaking. For example, the investment strategies of retail investors usually build up a portfolio involving a few firms (Barber and Odean, 2013). Because of the small size of the portfolio, the crash risk of each constituted firms probably fluctuates the investment's returns, thereby undermining the retailer investor's personal wealth. Hence, acquiring knowledge about determinants of crash risk helps to protect the value of shareholders.

In this research, we explore a new determinant of stock price crash risk, which is equity option market liquidity. There are three parts in this chapter. The first part outlines the formation mechanisms of crash risk (Chen *et al*., 2001). Based on the governance theory and short-termism theory, the second part investigates the role of market liquidity in crash risk (Chang *et al*., 2017). The last part explains other determinants of crash risk (Habib *et al*., 2018).

8.1 Formation Mechanisms of Stock Price Crash Risk

Stock price crash risk is defined as a large negative outlier in the distribution of stock returns which causes long left tails in this distribution (Kim *et al*., 2014). The extant theoretical literature puts forward several mechanisms demonstrating how crash risk is formed, such as bad information hoarding theory, information blockage, volatility feedback effects, the default risk-based explanation and incorporated heterogeneity in investors' beliefs (Chen *et al*., 2001; Habib *et al*., 2018). Among all these mechanisms, the bad information hoarding theory is the most widely recognized by academia (Habib *et al*., 2018).

8.1.1 Agency Theory based on Managerial Incentives for Hoarding Bad News

Proposed by Jin and Myers (2006), the agency-based theory provided a theoretical foundation for crash risk, which supports that the problem with asymmetric information between corporate insiders and external stakeholders is the principal determining factor of crash risk. The emphasis of this theory is on the managers' superior ability to gather and release bad news. Managers have the power to choose what type of information and pick a time to announce the news. These capabilities induce managers to behave opportunistically and hoard the negative news in the pursuit of their career and compensation (Kothari *et al.,* 2009). The asymmetric distribution of stock returns becomes more significant when managers keep covering the bad news continuously (Cao *et al.,* 2002).

However, the ability of managers to pile up negative information is limited by the costs of information hiding behaviour. Once the accumulation of negative information beyond the tipping point, this information disseminates to the public immediately. Investors will reassess their expectations of firms' prospects. Their responses catalyse inflated share prices getting closer to their true value eventually, resulting in stock price crash risk. Therefore, the managerial incentives to withdraw negative information leads to abrupt decreases in share prices.

8.1.2 Volatility Feedback Effects

Regarding the traditional financial theories, most of them focus exclusively on the role of representative investors in the crash risk formation. Yet, the importance of volatility feedback effects in the crash risk generation mechanism should not be undermined (French *et al*., 1987; Campbell and Hentschel, 1992; Soo-Joon *et al*., 2020). It interprets the negative relationship between volatility and stock price as follows: 'big price movements could cause investors to reassess market volatility and increase required risk premia. An increased risk premium reduces equilibrium prices, which reinforces the impact of bad news but offsets the impact of good news, thus generating negative skewness' (Hutton *et al*., 2009). As a result, even in the presence of the symmetrical process driving news, the return (especially the return of the market portfolio) exhibits as the negatively skewed (Hong and Stein, 2003).

However, Poterba and Summers (1986) expressed scepticism that the shocks to volatility are short-lived in most cases, which may not significantly influence the risk premiums. Recent studies (e.g., Glosten *et al*., 1993; Bollerslev *et al*., 2009) provided an abundance of evidence rebuttal to the argument of Poterba and Summers (1986), showing that the arrival of bad news causes higher market volatility than positive market shocks of the same magnitude, which triggers stock price crashes.

8.1.3 The Default Risk-Based Explanation

Earlier theories of leverage effects (Black,1976; Christie, 1982) indicated that a decline of stock price increases operating and financial leverage, thereby causing the volatility of subsequent stock returns. Based on these explanations, the default risk-based theories for stock price crash risk shows that firms are subjected to the default risk are highly possible to disclose extremely negative information or extremely positive information. In a different situation, they will experience business failure or continue as a going concern[47]. If the firms expose to great default risk and are threatened by business failure, it is highly likely for them to face crash risk. The prior literature proxied firm size and leverage as default risk, however it should be cautious that the validity of these proxies is questioned by other scholars (Hutton *et al*., 2009; Kim *et al*., 2011a, b). By contrast, in reality, leverage is negatively linked to crash risk when there is a positive connection with bankruptcy risk (Campbell *et al*., 2008). The potential reason behind this surprising evidence is that investors initially underprice firms with high leverage, thus making the less likelihood of subsequent crash risk. In accordance with this reasoning, highly leveraged firms generate greater future averaged returns than lowly leveraged firms (Zhu, 2016).

8.1.4 Incorporated Heterogeneity in Investors' Beliefs

Different from the representative-investor theories, such as the default risk-based explanation and volatility feedback effects, the theoretical arguments of Hong and Stein (1999, 2003) indicated that an incorporated heterogeneity in investors' beliefs is possible to release the private signals of relatively pessimistic traders and becomes a driving factor of return asymmetries. Two

[47] 'Going-concern opinions (GCO) represent an important way in which the auditor communicates with the shareholders about her substantial doubt that the client can continue as a going concern. GCO represents mainly the independence dimension of audit quality, because managers are motivated to avoid GCO given its serious capital-market consequences. For example, auditors would likely lose the clients after issuing GCOs' (Hope *et al*., 2017)

principal assumptions are the investors' opinion differences about the market fundamental value and the constraints of short selling (e.g. mutual funds cannot short sales). When opinion differences are initially large, an increasing number of bearish traders are forced by the short-sales constraints to formulate a corner solution strategy. Because of being at a corner, the information of their stock selling, and existing positions is not fully incorporated into the stock prices. Nevertheless, previously-more-bullish traders change their investment strategies and withdraw from the market when the hidden information is gathered. Then the originally-more-bearish traders are likely to be the marginal 'support buyers'. Hence, the accumulation of concealed information tends to reach the threshold point in the market downturn, implying the negatively skewed return. Empirically, as trading volume represents the intensity of disagreement, the negative return skewness becomes more significant in the subsequent periods, in particular after large trading volumes.

8.1.5 Information Blockage

An 'information blockage' model [48] created by Cao *et al*. (2002) explained the formation of stock price crash risk. The core of this argument is that informed traders are attracted by rising prices to participate in active trading activities while traders possessed less information raise doubts about the true nature of the signals and delay a trade until the prices decline, which internally releases further information to the market. Therefore, market pessimism and the entry of the less informed marginal traders result in price correction. Information blockage leads to (1) negative skewness of return distributions following price upward but positive skewness following price downward; (2) the inexistence of correspondent relation between great price fluctuations and external information arrival; (3) increasing volatility following a considerable shift in stock prices (Cao *et al.*, 2002; Zhu, 2016).

To summarize, extant literature has placed great emphasis on the agency-based arguments of managerial incentives for bad news hoarding. However, in the investor's perspective, heterogeneous investor belief may trigger crash risk. It is hard to create a direct measure of

[48] Information blockage is 'the blockage in the pipeline that transfers individual information to the market'. 'This pipeline intermittently clogs and then releases information in large lumps.' The particular market imperfection, such as the fixed setup costs of trading, is regarded as a source of information blockage. The fixed setup costs of trading represent the conditional patterns of volatility and skewness (Cao *et al*., 2002).

heterogeneous investor belief, which slows down the pace of research on its effects on crash risk. Due to these technical difficulties, there are no convincing studies to empirically analyze whether the stockpile of negative information intensifies investor heterogeneity will contribute to the stock price crash risk. Furthermore, debt covenant violation is a better measure than firm size or firm leverage to represent default risk, which helps to interpret the reason why firms subject to high default risk tend to experience more crash risk (Habib *et al*., 2018).

8.2 The Effects of Market Liquidity on Stock Price Crash Risk

In this research, we will explore the relation between asset market liquidity and stock price crash risk. Following the work of Chang *et al*. (2017), firms with higher market liquidity are considered to suffer from greater crash risk.

8.2.1 The Positive Effect of Market Liquidity on Stock Price Crash Risk

According to transient investor channel in short-termism theory and blockholder exit mechanism in governance theory, market liquidity positively affects stock price crash risk via cutting-and running' selling executed by transient investors [49] (Fang *et al*., 2014) and effective blockholders' exit (Edmans, 2009).

1) Short-Termism Theory (Transient Investor Channel)

Stein (1989) defined managerial short-termism (namely, managerial myopia) as the 'desire to achieve a high stock price by inflating current earnings at the expense of long-term growth'. Some studies (e.g., Jacobs, 1991; Porter, 1992) have criticized the managers who are obsessed with short-term performance and exhibit myopic investment behaviour in US. Existing research recognised managerial short-termism is a universal phenomenon. For example, 78% of executive directors achieve the targets of short-term earnings at the expense of long-term value (Graham *et al*., 2005). Krehmeyer *et al*. (2006) and Dichev *et al*. (2013) also produced similar findings to

[49] 'Bushee (1998) classifies institutional investors into transient investors, quasi-indexers, and dedicated investors. Transient investors are characterized by high portfolio turnover and momentum trading, quasi-indexers by following indexing strategies and holding fragmented diverse portfolios, and dedicated investors by concentrated portfolio holdings and low portfolio turnover' (Fang *et al*., 2014). An increasing number of transient investors and quasi-indexers amplify the managerial myopia problem because these investors have less interest in collecting fundamental information or monitoring managers' behaviour (Porter, 1992). Therefore, Fang *et al*. (2014) categorized transient investors and quasi-indexers into nondedicated investors.

support the managerial short-termism conclusion. Hence, they decided to investigate the influential factors contributing the managerial short-termism (Edmans, 2009). Market liquidity is one of the widely recognized factors of managerial short-termism (Chen *et al*., 2015; Kang and Kim, 2017; Chang *et al*., 2017).

Mounting studies criticized that market liquidity is the culprit of short-termism. Yet, it is noteworthy to mention that not all investors act in similar manners (Kang and Kim, 2017). For instance, dedicated traders have long-term investment horizons while transient traders have short time horizons (Bushee, 1998). Accounting for the traders with different horizons, managerial myopia problems are exacerbated by greater market liquidity, arising from the myopic blockholder formation and their exist based on the bad news (Chen *et al.*, 2015).

Higher market liquidity facilitates the formation of myopic blockholders (Coffee, 1991; Porter, 1992; Bhide, 1993). Porter (1992) indicated that a large proportion of U.S. institutional investors are indeed transient. They raise the short-term price and exist in response to the bad earnings news. When the market liquidity is high, the corresponding large monitoring costs discourage more blockholders from collecting private information and considering the true long-term value, which impedes firms' long-term investment (Fang *et al*., 2014; Asker *et al*., 2015). In other words, short-term oriented blockholders are easily formed in a liquid market.

Furthermore, low trading costs in the liquid market promote transient investors to enter and exit the market, so they concentrate excessively on short-term performance and eventually establish short-term investment horizons (Porter, 1992; Fang *et al*., 2014). As stated by Bhide (1993), 'stock liquidity discourages internal monitoring by reducing the costs of 'exit' of unhappy stockholders', short-term oriented investors are forced to 'exit' their position hastily due to unfavourable short-term performance information (Coffee, 1991; Roosenboom *et al.,* 2014). The downward pressures exerted on prices from their stock selling push managers to withhold bad news and increase short-term earnings growth (Matsumoto, 2002). Consequently, the immediate release of accumulated bad news triggers 'cutting-and running' selling by transient investors and results in crash risk. Furthermore, greater market liquidity facilitates the exist of blockholders when bad news releases (Edmans, 2009). The huge selling pressure from short-term oriented blockholders generates positive feedback trading by momentum investors, which leads to stock price plunges and ultimately creates target companies for takeover (Stein, 1989; Bhide, 1993). Put it simply, under the short-termism pressures, higher market liquidity magnifies the response of transient traders to bad news disclosures, which leads to a cutting-and-running type of selling. Myopic blockholders face larger downward stock price pressures and engage in short-termism investment behaviour with greater market liquidity.

By and large, as indicated by short-termism theory (Porter, 1992; Fang *et al.*, 2014), low transaction costs improve asset market liquidity and draw the attention from an increasing number of transient institutional traders who concentrate exclusively on the short-term firm performance and usually adopt a short-term investment strategy. Managers may hoard negative information to boost short-term earnings when they cope with the downward pressure exerted by these traders on the stock price. Subsequently, the concealed information is accumulated beyond the threshold level. Managers have no alternative and reveal this information to the public immediately, which causes 'cutting-and running' selling by transient investors and hence generates crashes.

2) Governance Theory (Blockholder Exit Mechanism)

Businesses that acquire the assets comfortably and successfully can gain a competitive edge in the relevant industry, and Thurow (1993) contended that this is the reason why U.S. firms dominate in the global market. Nevertheless, managerial myopia may result in an inefficient investment. As indicated by Berle and Means (1932), the separation of ownership and control leads to agency problem, which reduces the managers' incentives to realize value maximization and damages the benefits of shareholders. Managerial myopia is the tendency of managers to obtain short-term benefits rather than long-term gains. Therefore, revolving around the short-term share price mainly may lead to managers' investment failure.

Blockholders are regarded as a solution to alleviate the myopia problem. Rubin (2007) and Boehmer and Kelley (2009) provided theoretical models in which blockholders have a superior ability to make profits from negative information and are strongly motivated to become informed. In Edmans (2009) point of view, blockholders have a good understanding of the effects of poor firm quality or the long-term investments on lower returns. Desiring to collect such costly information about fundamental value of firms strongly, blockholders causes stock prices to fully capture fundamental value rather than short-term earnings.

Proposed by Hirschman (1970), there are two major corporate governance mechanisms, which are intervention and exit. Some traditional studies on blockholder governance assume that voice is the sole way for blockholders to implement governance. Voice is a direct corporate intervention to realize strategic changes by means of public shareholder proposals, private letters to management and voting against directors.

As blockholders are small and constrained by the huge legal and institutional barriers in the US, blockholders choose to exist when they are not capable of engaging in voice activities (Edmans, 2009). Recent research pointed out the second governance mechanism in which a firm trades stocks, which refers to exit. Blockholders sell shares and reduce stock price ex-post to punish managers who damage firm value. Ex-ante, managers are forced by the threat of exit to realise firm value maximum. Parrino *et al.* (2003) presented direct evidence of exit. Blockholders without control rights indirectly exert the effect of corporate governance.

As discussed above, corporate governance is improved by a larger extent through blockholders' voice and exit, thereby maximising firm value. Nevertheless, the natures of voice and exit are distinct in many aspects. Voice theories present the causes and consequences of shareholder activism, while exit theories analyse the effects of blockholders' exist on financial markets and the effects of microstructure factors on their existing effectiveness (Edmans, 2014).

In addition to these two corporate governance mechanisms, there is a third mechanism as another potential candidate to explain why blockholders affect firm value. It shows that blockholders exacerbate agency problems through achieving private benefits against small shareholders or other channels (Edmans, 2014). The behaviour of blockholders can enhance firm value ex-post, but their presence is possible to undervalue ex-ante. For example, the threat of intervention reduces managerial initiatives and lowers market liquidity.

The profits of blockholders are mainly made in two ways. One is to trade against liquidity investors. Blockholders have a greater ability to access private information than other market participants through monitoring a firm or ‘cutting and running’ selling. Blockholders will earn profit based on their superior ability to gather information. Another profit-making method is by purchasing the initial shares. As initial shares are lower than their intrinsic value, liquidity investors suffer expected loss from their future trades with informed investors (e.g. blockholders) when liquidity investors hold stakes at an adverse selection discount. In the meantime, blockholders earn trading gains from liquidity investors. To respond this profit-making opportunity, the blockholders firstly gather the information and then develop the corresponding trading strategy as in Rubin (2007) and Boehmer and Kelley (2009).

As exit is also the most frequently used governance mechanism (McCahery *et al*., 2016), we particularly investigate the determining factors of blockholders’ exist, such as block size and market liquidity in this part.

Different from other investors (such as speculators without a stake), blockholders will gather private information on firm value with interventions, so they play a more special role in corporate governance through exist. The association between block size, the incentives to acquire information, and informed trades are established in Edmans (2009). Regardless of their stakes, investors can collect information through costly monitoring. As investors who have a zero position cannot trade upon negative information, the presence of short-selling constraints reduces their information acquisition incentives. To some extent, the larger stakes encourage them to sell stocks on negative information and generate greater incentive to collect information at the outset. Nevertheless, under the circumstance of sufficiently large stakes, liquidity constraints increase the price impact and discourage blockholders’ stock selling. The finite block size at the optimal level is in accordance with the prevalence argument of small US blockholders (Edmans, 2014).

Apart from block size, market liquidity also improves the effectiveness of blockholders’ exit. Edmans (2009) proxied a parameter for the trading volume of liquidity investor demand as liquidity and presented three ways of promoting blockholders’ exit. Firstly, with constant personal information, blockholders trade more actively on their information. Secondly, in the case of constant block size, blockholders collect a larger amount of private information to gain more trading earnings. Thirdly, because of the increased liquidity, blockholders could acquire larger initial block and sell more shares on bad news. A drawback of market liquidity is the limited effects of given transaction size on stock price, owing to the reason that informed trading from blockholders is covered by the uninformed trading from liquidity investors. Nevertheless, market liquidity exerts positive effects on the informativeness of stock prices, which increases managers' incentives to expand the firm value. Admati and Pfleiderer (2009) did not characterize liquidity investors but emphasized that the blockholders' governance through the exit is less effective with greater market illiquidity, which is proxied as higher transaction costs. In other words, market liquidity improves the governance of blockholders, especially blockholders' exit.

Although market liquidity increases the blockholders' capacity to monitor corporate management through initial block formation and trading profit-making (Maug, 1998), the exit of blockholders continues to take place and leads to crash risk. On this basis, firm value is assumed to be determined by managerial efforts and exogenous shocks. Higher liquidity gives rise to greater exit threats and motivates managers to make greater efforts, which leads them to make investment decisions more efficiently and engage in less bad news holding activities. Nevertheless, negative shocks, such as bad industry conditions, lead to the existence of negative information. Compared with other investors, blockholders have a superior ability to process the news. Thus, higher liquidity may facilitate the exist of blockholders with the disclosure of bad news (Edmans, 2009).

In short, when unfavourable information is disclosed, higher market liquidity can promote blockholder exit. The huge selling pressure exerted by blockholders amplifies the market reaction to the firm-specific bad news, resulting in the stock price crash risk.

8.2.2 The Negative Effect of Market Liquidity on Stock Price Crash Risk

Based on the external monitoring mechanism in governance theory and the information production efficiency hypothesis in short-termism theory, market liquidity negatively influences stock price crash risk via better blockholders' governance (Edmans, 2014) and greater price informativeness (Holden *et al.*, 2014).

1) Governance Theory (External Monitoring Mechanism)

In contrast to the blockholder exit mechanism mentioned above, the external monitoring mechanism indicates that enhanced market liquidity facilitates blockholders' governance on firm management via building block and making trading gains from intervention, which curbs managerial bad news holding activities (Edmans, 2014). Therefore, stock price crash risk declines (Maug, 1998; Edmans, 2009). This part will systematically discuss how the external blockholders' monitoring reduces crash risk.

In governance theory, blockholders have the motivation to monitor firms (Maug, 1998). 'Monitoring' is a label to reflect firms' value-enhancing activities, also known as 'intervention' and 'shareholder activism'. It contains the corporate intervention in affairs and the access to information, which is used to identify the potential intervention targets. Due to larger stake, blockholders adopt an attitude in favour of shareholder activism. They hold larger initial stake to commit more interventions while they use smaller shares to avoid this commitment.

The major reason behind blockholders' monitoring and trading is that blockholders have strong desires to collect information. Following the closed-form models created by Kyle (1985) and Edmans (2009), they showed that the demand of liquidity trader and firm value derive informed trading, the amount of information and news they acquire will eventually determine the optimal trading volume. Thus, this will incentive the blockholders to collect as much information as possible.

Blockholders hold stakes large enough to justify intervention costs, but they can choose not to intervene (Edmans, 2014). As block size determines the blockholders' incentives to intervene (Winton, 1993; Noe, 2002), blockholders adjust block size to influence voice's strength (Edmans and Manso, 2011). For example, voice weakened by splitting a block among multiple traders (known as 'cut and run') amplifies the free-rider problem and thereby reduces the intervention incentives of each investor. As stock price contains intervention possibility, blockholders can endorse the trading strategy of cut and run to make profit from selling stocks rather than managerial intervention (Kahn and Winton, 1998). Therefore, the option to 'cut and run' causes asset market liquidity.

Various theories of voice hold differing views about the effects of market liquidity on intervention. Some studies (e.g., Coffee,1991; Bhide, 1993) put forward an idea that market liquidity promotes cutting and running and thereby hinders intervention. As evidence, the dominated 'cutting and running' effect is caused by the typically large stakes chosen in the IPO (Back *et al.*, 2015). By contrast, others indicated that greater asset market liquidity encourages blockholders to commit more interventions. Liquidity not only promotes block formation from the start (Kyle and Vila 1991; Maug 1998; Kahn and Winton 1998), but also provides opportunities for blockholders to earn trading gains from their intervention (Maug 1998; Faure-Grimaud and Gromb, 2004). Overall, liquidity promotes blockholders' intervention (Edmans, 2014).

Market liquidity facilitates the formation of initial block. In Maug (1998), there are two ways for blockholders' to make profits, which are buying the first-period stake (a) at a discount and trading against liquidity investors who buy the stock (a) in the second period. The fear of the losses to the blockholders in the second period induces liquidity investors acquiring first-period block size (a) to sell at a lower price. Market liquidity generates a better discount for blockholder to buy stake (a) but does not influence their targeted stake size (Edmans, 2014).

Furthermore, market liquidity increases the expected gains from blockholders' trading upon private information. Although blockholders' monitoring costs are not fully covered by the capital gain from their initial stakes, the ability to acquire additional stock shares at a price that does not reveal the information about the blockholders' improvements exert some efforts to incentivize the firms monitoring. Thus, blockholders can cover monitoring costs through informed trading in more liquid markets, which encourages them to engage in more monitoring activities. In a different situation, by preventing potential losses, a less liquid market induces blockholders to avoid the commitment to monitor by improving their investment portfolio diversification and holding smaller stocks in more firms (Maug, 1998). Furthermore, Faure-Grimaud and Gromb (2004) indicated that intervention creates the value that may only be reflected in the long period.

As the benefits from intervention cannot be realized in the short time, liquidity shock forces blockholders to sell stocks at a price below fundamental value. Encouraged by stock liquidity, speculators (such as hedge funds) who have a superior ability to acquire information about the fundamental value by their monitoring improve their trading in markets. This informed trading keeps stock price near a fundamental value and helps blockholders to obtain profits from intervention even they sell stocks early. In short, blockholders can earn more trading gains from corporate intervention when market liquidity is higher and vice versa.

In short, market liquidity benefits blockholders' governance through the two channels, which are building block and earning trading gains from intervention (Edmans, 2014). According to the external monitoring mechanism discussed in the classical governance theories, a higher level of asset market liquidity promotes the blockholders' supervision of firm management and curbs managerial bad news holding activities, thereby reducing stock price crash risk (Maug, 1998; Edmans, 2009).

2) Short-Termism Theory (Information Production Efficiency Perspectives)

In recent studies, higher market liquidity promotes comprehensive information incorporated into the stock price and increases the probability of blockholders' formation. Therefore, it not only encourages blockholders to engage in long-term investment activities, but also facilitate corporate governance efficiency and firm performance (Fang *et al*., 2009; Edmans *et al*., 2013). In short, market liquidity impedes managerial short-termism.

Larger market liquidity affects managers' decision making via large information production and reducing market frictions (Holden *et al*., 2014). Firstly, market liquidity enhances the private information acquisition ability by reducing the cost of exploiting it, so the information of the true value of long-term investments contained in stock prices becomes more comprehensive when market liquidity is higher (Boehmer and Kelly, 2009; Bond ***et al*.**, 2012; Brogaard *et al*., 2017). The informative stock prices promote information production incremental to the information set of managers and act as guidance in managers' decision-making. Secondly, the equity premium is lower with enhanced market liquidity, reducing capital costs and altering capital structure decisions. Thirdly, due to the lower discount rate in the liquid market, the expanded scopes of positive NPV projects improve investment decisions. Lastly, decreasing transaction costs enhance the capital structure of firms and their payout policy. As a result, firms reduce managerial myopia and make better long-term investment decisions through stronger governance in the liquid market (Kang and Kim, 2017).

In addition, Maug (1998) theoretical argumentation indicated that the formation of blockholders is easier when market liquidity is high, thereby facilitating blockholders' trading. Empirically, Gerken (2014) proxied the tick size reduction as an instrument to break the endogenous relationship between block formation and market liquidity. In his paper, he showed that the reduction of tick sizes enhances market liquidity which improves the likelihood of blockholders' formation. When market liquidity is higher, blockholders can unwind their position with less significantly negative price effects (Edmans, 2009; Edmans and Manso, 2011). Therefore, in the liquid market, blockholders have a strong desire to collect costly private information on the fundamental quality of firms and innovating-type investment. Due to the superior ability to gather information, they can monitor corporate management either by improving voice (Maug, 1998) or by elaborating the threat of exit (Edmans, 2009; Edmans and Manso, 2011).

Overall, higher market liquidity increases both the production of information and the proportion of informed trade, which encourages greater price informativeness about the fundamentals of corporate economics. Under this circumstance, the ability of managers to accumulate negative information in the long term is restricted, thus lowering the crash risk (Holmstrom and Tirole, 1993; Holden *et al*., 2014).

8.2.3 The Summary of the Effect of Market Liquidity on Stock Price Crash Risk

The extant literature indicates that the immediate release of abundant bad news concealed by the company's management leads to stock price crash risk. It indicates that stock liquidity affects crash risk through influencing one or more of 3 items as following: the likelihood of bad news formation (i.e., the possibility of bad news due to poor management or negative shock), the extent of managerial bad news hoarding (i.e., whether, once bad news occurs, it is disclosed or accumulated by managers), and the strength of the market response with the disclosure of bad news (Chang *et al*., 2017).

Based on the governance theory and short-termism theory, we propose opposite hypotheses regarding the effects of market liquidity on the three items related to stock price crash risk in this part. For convenience, we summarize the theoretical predictions in the following table:

Bad News Hoarding Theory	Governance Theory		Short-Termism Theory	
	Blockholder Exit	External Monitoring	Transient Investor Channel	Information Production Efficiency
Bad News Formation	Decrease	Decrease	N/A	N/A
Bad News Hoarding	Decrease	Decrease	Increase	Decrease
Market Response to Bad News Releases	Increase	Ambiguous	Increase	Decrease
Net Effect on Crashes	Increase	Decrease	Increase	Decrease

Notes: This table presents the theoretical predictions regarding the effects of market liquidity on the three crash risk items. 'Increase' ('Decrease') indicates that higher market liquidity increases (decreases) the extent of the crash risk item. 'NA' indicates that there is no clear prediction. 'Ambiguous' indicates that the net effect of market liquidity on the crash risk item is unclear because of conflicting predictions. The last row summarizes the net effect of market liquidity on crash risk for each hypothesis.

Table 8.1 Theoretical Predictions Regarding the Effect of Market Liquidity on Crash risk

1) The Likelihood of Bad News Formation

In this part, we outline the relationship between market liquidity and the likelihood of bad news formation. In governance theory, we present two corporate governance mechanisms, which are blockholder exit and blockholder monitoring. In blockholder exit mechanism, a close association between managerial compensation and share prices, ex post, causes managers to sustain losses from stock price downturn owing to blockholders' stock selling based on private information (Edmans, 2009; Edmans and Manso, 2011). Hence, ex ante, the threat of blockholder exit guides managers to invest rationally in the best interests of shareholders and prevent them from participating the value-destructive activities (Admati and Pfleiderer, 2009).

Furthermore, in blockholder monitoring mechanism, blockholders' ability to monitor firm management is facilitated by greater market liquidity which deters managers from making value-destroying investment decisions through share accumulation and increasing intervention profits (Kahn and Winton, 1998; Maug, 1998). Therefore, based on governance theory, market liquidity decreases the likelihood of bad news formation.

2) The Extent of Managerial Bad News Hoarding

In this part, we discuss the connection between market liquidity and the extent of managers' bad news hoarding. Regarding the governance theory, market liquidity reduces bad news hoarding activities. Firstly, informed investors trade against liquidity investors and earn trading gains from private information. As a result, market liquidity increases the marginal value of information acquisition. Informed investors are encouraged to enhance information production and facilitate their aggressive trading on private information, which facilitates the information incorporated into stock prices (Holmstrom and Tirole, 1993). Secondly, market liquidity helps blockholders to collect costly information and promotes their informed trading. In other words, informative stock prices impair the bad news holding ability of managers when these prices reflect the economic fundamentals of firms (Edmans, 2009).

In short-termism theory, two competing hypotheses including information production efficiency perspective and transient investor channel are proposed. The prediction of information production efficiency perspective is in accordance with governance theory, which supports the alleviated effects of market liquidity on bad news hoarding activities. In a liquid market, large information production and reducing market frictions determine managers' decision making (Holden *et al*., 2014). The long-term information incorporated in stock prices alleviates the managerial myopia problems, thereby reducing the participance of transient investors (Boehmer and Kelly, 2009; Bond *et al*, 2012; Brogaard *et al*., 2017). Furthermore, market frictions, such as equity premium, discount rate and transaction costs, play a less significantly adverse role in the long-term investment decisions.

By contrast, the transient investor channel puts forward the line of reasoning that market liquidity promotes investors' ability to stockpile bad news by exerting short-termism pressures. The great majority of US institutional traders, who seek the appreciation of short-term price and exist due to the low reported earnings, are defined as transient traders in Porter (1992). Low transaction costs in the liquid market make them easier to enter and exit (Fang *et al.*, 2014) so that transient institutions prefer the firms which have higher expected short-term earnings and exert the pressure on managers to excessively focus on short-term (Bushee, 2001). To alleviate the selling pressure from transient investors on stock price, an increasing number of short-term-focused managers hold negative information to retain reported earnings (Matsumoto, 2002).

3) The Strength of the Market Response with the Disclosure of Bad News

In this part, we investigate the effect of market liquidity on the strength of market responses related to unfavourable information. In governance theory, blockholder exit mechanism shows that the costs of unhappy stockholders' exit decrease with enhanced market liquidity (Bhide, 1993), which exacerbates market responses to bad news. Furthermore, in short-termism theory, the transient investor channel indicates that the response of transient institutional investors to the disclosure of unfavourable information is magnified by enhanced market liquidity and this is evidenced as 'cutting-and-running' selling by transient investors (Edmans, 2009). Therefore, these two hypotheses support that greater market liquidity magnifies market responses to bad news, resulting in stock price cash risks.

By contrast, in short-termism theory, the information production efficiency perspective presents opposing points of view. Market liquidity enhances the production of information and increases the proportion of informed trade, which generates greater price informativeness about the fundamental values of corporations. In this situation, blockholders can unwind their position with less significant adverse effects on the stock price. As a result, stock price crash risk decreases.

Nevertheless, in governance theory, the blockholder monitoring mechanism has ambiguous predictions about the effects of market liquidity on market response to unfavourable information. On the one hand, the trading of informed investors on private information weakens the responses of their trading to public bad news disclosures. This is because stock prices reflect unfavourable information, especially when explained clearly by traders (Chang *et al*., 2017). On the other hand, blockholders have superior information gathering ability and sell stocks more aggressively than other traders when bad news releases. Consequently, the exist of blockholders may exacerbate the market responses to negative information, resulting in stock price crash risk (Edmans, 2014).

In summary, there are competing hypotheses of the effect of market liquidity on stock price crash risk. On the one hand, higher market liquidity leads to reduced crash risk. The likelihood of bad news formation lowers with either intervention or the threat of exit when market liquidity increases. Due to the larger information production and greater stock price informativeness, managers are less capable of withholding unfavourable information. In addition, enhanced market liquidity alleviates the responses of informed traders to bad news disclosures.

On the other hand, higher market liquidity causes more significant stock price crash risk. An increasing number of transient institutional investors induced by market liquidity piles up negative information and eventually exhibits cutting-and running selling when accumulated bad news is made public immediately. What is more, the market responses to bad news disclosures are magnified by blockholders' exit. As a result, crash risk increases. Thus, it is essential to provide empirical evidence to find which effect will prevail.

8.3 The Determinants of Stock Price Crash Risk

We show some influential factors and consequences of firm-specific stock price crash risk. These factors are classified into five catalogues, such as 'financial reporting and corporate disclosures, managerial incentives and managerial characteristics, capital market transactions, corporate governance mechanisms, and informal institutional mechanisms' (Habib *et al*., 2018). Among these catalogues, we pay special attention to a few of factors, such as asymmetric information, short interest, and option trader sentiment.

8.3.1 Asymmetric Information between Managers and External Shareholders

Dozens of studies on stock price crash risk generally indicate that bad news hoarding behaviours result in crash risk (Jin and Myers, 2006; Kothari *et al.,* 2009; Hutton *et al*., 2009). They suggested that managers who pursue career and short-term compensation plans hide bad news from investors, but they are prone to give up when the accumulated bad news reaches a tipping point. At that point, all the negative news specific to firms were immediately made public, thereby leading to crash risk. The crash risk is reflected as an extremely high negative outlier in the return distribution. The empirical evidence suggested that managerial bad news hoarding activities usually exist in the forms of corporate tax avoidance activities and accrual manipulation. More than that, a worse external investment environment, including institutional investor instability and a less-religious head office milieu, also contributes to greater crash risk (Hutton *et al.***,** 2009; Kim *et al.*, 2011a; Callen and Fang, 2013).

Based on the agency theoretical framework of Jin and Myers (2006), the presence of information asymmetry between corporate insiders and external shareholders is the main reason which allows the manager to behave opportunistically and hoarding bad news. Consequently, stock price crash risk is developed. As they argue, in an attempt to boost their compensation, promote employment and reduce litigation concerns caused by bad news disclosures (Kothari *et al*., 2009), managers will withhold the information about the firm from the public but with limited capacity. By exploiting their advantages and positions, managers will hide their investment and operating decisions, particularly those related to their personal and temporary bad performance, from the external investors. Thus, the public will have difficulty assessing the cash flow, firm, and managerial performances if this firm-specific bad news is hidden intentionally. When the amount of this concealed information accumulated continually and beyond the threshold level, managers have no choice and will reveal this information publicly at once. Consequently, this will cause the crash risk. Regarding the financial perspective, crash risk is a large negative outlier in the distribution of stock returns which causes long left tails in this distribution.

Empirical evidence supported that firms engaging in bad news holding activities expose a larger crash risk problem. Several factors related to hiding bad news, such as accrual manipulation (Hutton *et al*., 2009), corporate tax avoidance (Kim *et al*., 2011a), CFO's equity incentives (Kim *et al*., 2011b), equity ownership by transient institutional traders (Callen and Fang, 2013), positively affect stock price crash risk (Callen and Fang, 2015a, b). Alternatively, other factors concerning social norms and information disclosure, such as the location of headquarter with higher levels of religiosity (Callen and Fang, 2015a) and corporate social responsibility (CSR) disclosures (Zhang *et al*., 2016), curb bad news hoarding behaviour and eventually reduce crash risk. In short, a higher level of asymmetric information between managers and external investors increases the need for bad news hoarding and hence generates crash risk.

8.3.2 Short Interest

The mainstream research supported the notion that managerial bad news hoarding behaviour results in stock price crash risk (Jin and Myers, 2006). Short sellers are attracted by adequate profit from stock price crash risk and adept at identifying firms that are exposed to these crashes due to their bad news hoarding activities. Based on the studies of Staley (1997) and Chanos (2003), the short sellers' decisions are made by collecting superior information from different sources, such as 'financial statement, proxy and insider filings, marketplaces, trading patterns, media and others.' Hence, short sellers are regarded as sophisticated traders because they can recognize firms' bad news hoarding behaviours and predict crash risk. They will short stocks at the end. Their trading activities result in a positive association between short interest and stock price crashes.

As short sales improve price efficiency (Bris *et al*., 2007; Karpoff and Lou, 2010), the positive relationship between short interest and crash risk is less significant than the above arguments discussed. Short sellers reveal the misconduct of firms and then bring stock prices closer to their fundamental value. If short sellers are not constrained by short selling and other market frictions, they will be perfectly informed. Short interests are unrelated to future stock price crash risk when stock prices are aligned with fundamental values (Callen and Fang, 2015b).

Nevertheless, in the real business world, short-sale constraints and arbitrage trades developed the more complicated markets. Short sales associated with various costs and risks (e.g., 'lending fees, recall risk, and regulatory restrictions') cause restriction to arbitrage and price inefficiency (Engelberg *et al*., 2018). Even though short sellers have strengthened information capacity to identify cash-prone firms, they ineffectively drive stock prices to keep step with fundamental values and fail to fully arbitrage the large stock overpricing, especially when a huge divergence between stock prices and fundamental values occurred (Shleifer and Vishny, 1997). Furthermore, stock price delays are triggered by numerous frictions, including short-selling constraints, information asymmetry, incomplete (accounting) information, the uncertainty of parameter, and market illiquidity problems (Hou and Moskowitz, 2005; Callen *et al*., 2013). In short, short sales improve price efficiency, but their ability limited by a number of costs and market risks causes price delay, which allows future studies conducted on the positive association between short interest and stock price crashes.

Furthermore, a variety of countervailing factors may lower this positive relationship, such as uninformed trading. In Brent *et al*. (1990), hedging activities and tax-based trading drive uninformed trading. If short positions are taken for the trading behaviour of uninformed investors rather than bad news activities of managers, the relationship between short interest and crash risk may not exist. What is more, legal or regulatory constraints deter informed traders from engaging in short-selling activities, thereby causing the absence of this relation (Christophe *et al*., 2010). However, these countervailing factors influence the short interest-crash risk relationship by adding noise other than bias.

The argumentation that agency conflicts between managers and shareholders lead to a higher likelihood of bad news formation becomes a prevalent theoretical foundation of the linkage between short sales and crash risk (Kothari *et al*., 2009; Hutton *et al*., 2009). Short sellers estimate the severity of agency conflicts and then identify firms engaging in bad news hoarding activities for anticipating crash risk. Furthermore, as noted by Callen and Fang (2013), firms that have weaker external monitoring mechanisms are easily subject to crash risk. Firms enduring severe agency conflicts are more likely to hide negative information from investors so that they are easily targeted by short sellers in anticipation of crash risk. Hence, a more pronounced relationship between short interest and crash risk is expected in firms with serious agency problems.

8.3.3 Investor Sentiment

Mounting papers pointed out internal characteristics of firms is associated with crash risk (Habib *et al*., 2018). However, only a few studies highlight the role of external investors in crashes establishment. Their empirical evidence showed that different investor behaviours such as investors' opinion differences (Chen *et al*., 2001), the information transmission from bearish investors constrained by short sales (Hong and Stein, 2003), the monitoring ability of institutional investors (Callen and Fang, 2013), market-wide sentiment (Yin and Tian, 2017), retail investor attention (Wen *et al*., 2019) as well as firm-specific investor sentiment index (Fu *et al*., 2020), all affect stock price crash risk.

In the previous research on the effects of market-wide sentiment on crash risk, market-wide sentiment inaccurately reflects individual firms' sentiment (Yin and Tian, 2017) and thereby cannot address firm-level issues (Aboody *et al*., 2018). Furthermore, Wen *et al*. (2019) proxied the frequency of Baidu searches for individual firm tickers as investor attention, but there are no sentiment tag references in these individual firm tickers. Thus, it is essential to construct a firm-specific investor sentiment index and analyse its influence on crashes. In Fu *et al*. (2020), it performed principal component analysis to extract a firm-specific investor index, based on price-earnings ratio, average turnover rate and buy-sell imbalance. It showed that firm-specific investor sentiment is positive to stock price crash risk. Further investigations indicate that their positive relationship is more significant when firms face reduced stock market liquidity. Overall, it reveals that firm-specific investor sentiment significantly affects stock price crashes. As we examine the effects of the new firm-specific investor sentiment indicator, which is the option trader sentiment in individual firms, on stock price crash risk, the empirical research is closest to ours is Fu *et al*. (2020).

Theoretically, consistent with the noise and rational trader argument proposed by Black (1986) and De Long *et al*. (1990), traders can be classified as two types, which are unsophisticated noise traders and rational arbitrageurs (namely, informed traders). Based on the trader classification, there are two types of firm-specific investor sentiment in the market, such as noise trader sentiment and rational arbitrageur sentiment. Following Figlewski (1989), option trader sentiment is one of rational arbitrageur sentiment.

Noise traders with a highly optimistic attitude towards individual equity are more capable of raising the price. At present, arbitrageurs can sell the stock short or buy more puts relative to calls, so option traders have high sentiment. Yet, they are afraid of a further price increase driven by the more optimistic noise traders and their original arbitrage positions limited by these noise traders. This is because noise comes with risks, and arbitrage cannot eliminate the noise effects on price (De Long *et al*., 1990). Stock price does not fully reflect the information of arbitrageurs, especially negative information.

Furthermore, managers intentionally hoard bad news by issuing optimistic earnings forecasts and recommendations during high option trader sentiment periods. In this situation, unfavourable information cannot transmit to outside investors timely (Xu *et al*., 2013). When the accumulated negative information reaches a threshold level, it will disclose to public immediately and contribute to crash risk (Jin and Myers, 2006). Hence, option trader sentiment acts as a new firm-specific investor sentiment proxy and expects to have a significantly positive effect on stock price crash risk.

Overall, more serious asymmetric information problem, larger short interest and higher option trader sentiment induce managers to cover negative information from investors and thus generates crash risk (Kothari *et al*., 2009; Callen and Fang, 2015b; Fu *et al*., 2020). As market liquidity affect crash risk through three channels, including the likelihood of bad news formation, the extent of managerial bad news hoarding, and the strength of the market response with the disclosure of bad news (Chang *et al*., 2017), it is expected that these three determinants of crash risk play an important role of the effects of market liquidity on crashes.

Chapter 9 Empirical Analysis of Option Liquidity and Stock Price Crash Risk

9.1. Introduction

Stock market crash risk refers to significant and sudden price declines in the absence of large public and material fundamental news. The occurrence of this extremely downward tendency for stock prices is rare but it causes investors to suffer heavy losses (Liu and Zhong, 2018). Regarding the formation mechanisms of stock price crashes, the most widely recognized argument is the negative information hoarding argument [50] which explains this circumstance appropriately (Bhatia, *et al*., 2014). Based on this argument, some influential factors of bad news hoarding behaviour and their influence process are identified in the extant studies on stock market crashes, such as information asymmetry (Jin and Myers, 2006; Habib *et al*., 2018), short interests (Callen and Fang, 2015b) and investor sentiment (Yin and Tian, 2017) and stock liquidity (Chang *et al*., 2017). This paper extends this stream of research and regards option liquidity as a new factor of stock price crash. Option liquidity is defined as the ability to trade a significant quantity of option in a firm at a low price within a short time (Cao and Wei, 2010).

This paper investigates the relationship between option liquidity and stock price crash risk, owing to the reason that option traders are able to reveal firms' adverse information and anticipate crash risk. Options act as investment vehicles with low price and high leverage (Black, 1975). These option characters attract informed investors to trade in option markets and subsequently spread their information into the equity market (Manaster and Rendleman, 1982; Biais and Hillion, 1994; Mayhew *et al.,* 1995). Furthermore, options trading provides viable alternatives for the investors who look for the opportunity to express their opinions about future stock price, but subject to underlying stock short sale restrictions (Figlewski and Webb, 1993; Phillips, 2011). Therefore, the ability of options trading affects firms' bad news hoarding behaviour and reflects future stock price crash risk.

[50] The negative information hoarding argument indicates that the accumulated bad information results in stock price crash (Chang *et al*., 2017). Because of compensation contracts, career concerns and empire building, firms are incentive to curb bad news from markets for an extended time. The bad news accumulation tends to maintain or accelerate price inflation, which continues to fuel the price bubble. Beyond the tipping point, this information will spread to the market at once and finally cause substantial stock price declines.

The negative information hoarding argument proposes that the immediate disclosure of abundant negative information concealed by managers results in crash risk. It implies that market liquidity influences crash risk via any one or more of the three items as following: the likelihood of bad news formation (i.e., the possibility of bad news due to poor management or negative shock), the extent of managerial bad news hoarding (i.e., whether, once bad news occurs, it is disclosed or accumulated by managers), and the strength of the market response with the disclosure of bad news (Chang *et al.*, 2017). According to the governance theory [51] and short-termism theory [52], we propose the competing hypotheses regarding the effects of market liquidity on the above three items related to stock price crash risk.

Several researchers support that higher market liquidity leads to reduced stock price crash risk. Regarding the external monitoring mechanism in the corporate governmence theory, option traders act as an external monitoring force to limit managers' adverse information hoarding activities. As high option liquidity (active options trading) improves the quality of underlying equity market, option liquidity is deemed as an external monitoring method to restrict management control over hiding bad information. It enhances efficient investment decision making and then decreases negative information formation possibility. This effect leads to lower future crash risk (Maug, 1998; Edmans, 2009). Furthermore, based on short-termism theory, the information production efficiency perspective suggests that option liquidity promotes continuous informed trading to uncover negative information about firms' economic fundamentals. The

[51] In Hirschman (1970), there are two major corporate governance mechanisms, which are intervention and exit. In the first mechanism, voice is a direct corporate intervention to realize strategic changes via public shareholder proposals, private letters to management and voting against directors. In the second governance mechanism, a firm trades stocks, which refers to exit. Blockholders (namely, large shareholders) sell shares and reduce stock price ex post to punish managers who damage firm value. Ex ante, managers are forced by the threat of exit to realize firm value maximum. Taking intervention and exist into consideration, recent academia does not draw a unanimous conclusion on whether market liquidity curbs managerial bad news holding activities to promote the blockholders' supervision or improve the effectiveness of blockholders' exit to exacerbate the market reaction to the firm-specific bad news (Maug, 1998; Edmans, 2009).

[52] Stein (1989) defined managerial short-termism as the 'desire to achieve a high stock price by inflating current earnings at the expense of long-term growth'. In fact, not all institutional investors are alike (Kang and Kim, 2017). For instance, dedicated traders are the traders who have long-term investment horizons while transient traders are the traders with short time horizons (Bushee, 1998). Accounting for the traders with different horizons, recent researchers hold different viewpoints of whether market liquidity hinders or facilities the more comprehensive information incorporated in stock price, thereby amplifying, or impeding managerial short-termism (Chang *et al.*, 2017).

more informative market price not only limits managers to accumulate unfavourable information over a long period of time, but also lessens the degree of information asymmetry across underlying equities and timely alerts the capital market of such adverse information. Consequently, information production facilitates to reduce stock price crash (Holmstrom and Tirole, 1993; Holden *et al*., 2014).

In other words, enhanced market liquidity decreases crash risk. The likelihood of bad news formation lowers with either intervention or the threat of exit when market liquidity increases. Due to the larger information production and greater stock price informativeness, managers are less capable to hoard unfavourable information. In addition, enhanced market liquidity alleviates the responses of informed traders to bad news disclosures. For these reasons, the following hypothesis will be tested:

H_1: Option liquidity decreases stock price crash risk.

Yet, an alternative view indicates that higher option liquidity increases crash risk. According to the blockholder exit mechanism of governance theory, the threat of the blockholder exit increases crash risk. Higher option liquidity benefits blockholder to withdraw. If the accumulated bad news releases immediately, raising selling pressure exerted by these large shareholders will amplify market response, and thus triggering plunging stock prices (Bhide, 1993; Edmans, 2009). Furthermore, based on the short-termism theory, transient institutional investors [53] are the investors who have short investment horizons and pay excessive attention to firms' short-term performance. Due to low trading costs and high leverage, an increasing number of these uninformed investors have blindly attracted by high option liquidity (Porter, 1992; Fang *et al*., 2014). They are more willing to engage in the arbitrage between equity option and underlying equity (Grossman, 1987; Grossman and Miller, 1988), which results in the reduction of equity market information efficiency (Liu, and Zhong, 2018). Simultaneously, they push the growing downward price pressure on company managers to withhold adverse information to exaggerate short-term earnings. Although some informed option traders trade against the management

[53] In Bushee (1998), transient investors are characterized by high portfolio turnover and momentum trading.

opportunistic behaviour by building up positions in more liquid options (Bhatia *et al*., 2014), a large amount of irrational investment from transient investors have more instantaneous, explosive, and pronounced effects on firm performance. When negative news is eventually announced, "cutting-and running" selling by transient investors will exacerbate the crash risk.

In other words, higher market liquidity causes more significant stock price crash risk. Increasing transient institutional investors induced by market liquidity piles up negative information and eventually exhibits cutting-and running selling when accumulated bad news is made public immediately at the end. What is more, the market responses to bad news disclosures are magnified by blockholders' exit. As a result, this crash risk amplifies. Thus, it is essential to provide empirical evidence to find which effect will prevail. For these reasons, the following hypothesis will be tested:

H_2: Option liquidity increases stock price crash risk.

Prior studies have established conflicting propositions about whether option liquidity indeed mitigates or amplifies stock price crash. This paper empirically investigates which effect prevails in US equity option markets. Equity option data is provided by Option Metrics. This database includes details about individual option instruments such as the underlying stocks, the exercise price, maturity dates, open interests as well as the implied volatility and the Greeks measures. Data for constructing the stock liquidity and stock price crash measures extract from the Centre for Security Research (CRSP). This database contains the daily closing bid and ask prices, trading volumes, the number of shares outstanding and the unique security identification that allows stock price data to be matched with the option data. Firm financial information from the merged Compustat/CRSP database.

To capture different dimensions of option liquidity, we measure option liquidity with different aspects of bid-ask spread, trading volume and open interest. Furthermore, we construct stock price crash risk as the negative skewness (NCSKEW), the down-to-up volatility (DUVOL), and the crash dummy (CRASH), respectively. Following Kim *et al*. (2011b), we perform the OLS models where continuous variables, including the negative skewness (NCSKEW) and the down-to-up volatility (DUVOL), are proxied as crash risk, and perform logit regression where dummy variable, crash dummy (CRASH) is the dependent variable.

By employing a large sample size of U.S. public firms from 2000 to 2015, we find that option liquidity positively affects crash risk. The evidence is consistent with the later argument that options with higher liquidity are more susceptible to crash risk. Firms with lower proportional bid-ask spread of their stock options, higher option trading volume or greater option interests are more susceptible to stock price crash. This relation is more apparent for firms when subjecting a higher degree of information asymmetry, larger short interests, or during the financial crisis and periods of high financial market or macroeconomic uncertainty. Besides these, the optionable stock liquidity is more significantly positive to market crash than un-optionable stocks.

More importantly, our paper makes several contributions to the academic field. Firstly, we contribute to the research on the determining factors of crash risk. Mounting studies explore the effect of stock liquidity on crash in different markets (Chauhan *et al*. 2017; Chang *et al*., 2017; Zhang *et al*. 2018; Wang *et al*., 2020). Several researchers shift their lights on the relationship between derivatives trading and crash risk, such as options trading (Bhatia *et al*., 2014), CDS trading (Liu *et al*., 2019) and equity index futures trading (Liu, and Zhong, 2018). The economic significance of these derivatives trading activities in terms of trading volume and open interest is obvious on crash risk. To the best of my knowledge, few studies examine the relevant issue of derivatives liquidity in the forms of bid-ask spread (Bhatia *et al*., 2014; Liu, and Zhong, 2018). This is the first paper to directly analyse how equity option liquidity contributes towards the crash risk in the underlying equity market.

Secondly, we connect firm-specific investor sentiment with crash risk from a new perspective of option traders. Previous literature explores the relationship between market-wide investor sentiment and stock market movements in different aspects of return (Renault, 2017) and volatility (Da *et al*., 2015). Recent articles turn their lights on the firm-specific investor sentiment, especially for unsophisticated noise traders (Fu *et al*., 2020). From a new angle of rational arbitrager (e.g., option traders), we use put-call ratio as option trader sentiment and explore the relationship between firm-specific informed trader sentiment and stock price crashes. We extend to the new field in the economic consequences of investor sentiment.

Furthermore, comprehending the distribution of extreme return helps individual traders not only improve portfolio diversification, but also construct the risk management in corporations effectively. We provide new insights to strengthen their ability to understanding the tail risk. A deeper understanding of the dynamics of option liquidity is useful to predict the crash risk (Chauhan *et al*., 2017). Furthermore, we enhance the participation of informed traders and embed negative news into the stock prices (Bhatia *et al*., 2014).

The rest of the paper is established as follows. Section 2 describes data source and variable measurements. Section 3 introduces empirical methodology. Section 4 presents the empirical findings. The final section concludes with a summary.

9.2 Empirical Methodology

This study examines the relationship between option liquidity and stock price crash risk. Initially, it introduces the disparate option market liquidity measures and then employs three firm-specific crash risk measures. Then, it examines the effect of option liquidity on future stock price crash risk.

9.2.1 Measurement of Option Liquidity

We capture the different dimensions of liquidity by using three measures, including bid-ask spread, trading volume and open interest. Firstly, option proportional bid-ask spread is calculated as the yearly average value of the difference between ask and bid prices, divided by their mid-quote price (Liu, 2006; Huang and Mazouz, 2018). Generally, the wider the bid-ask spread, the lower the option liquidity.

Secondly, the trading volume is the yearly aggregation of the volume across all options for each underlying stock (Mayhew, 2002). An option with larger trading volume exhibits greater market liquidity.

Finally, open interest is defined as the total open interest of options for each underlying stock on a yearly basis (Bhatia *et al*., 2014). An option with larger open interest indicates greater market liquidity.

As these three liquidity measures involve the non-linear effects, it uses the natural logarithm transformation of these measures as a proxy for option market liquidity.

9.2.2 Measuring Stock Price Crash Risk

According to Jin and Myers (2006) and Chang *et al*. (2017), stock price crash risk is constructed as a remote and negative outlier in the residual stock return for each firm. There are three measures to capture crash risk, which are the negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH) respectively. Firstly, this study calculates the daily firm-specific returns from the expanded market and industry index model regression for each firm and year (Hutton *et al*., 2009) as following:

$$\mathrm{r_{j,t}} = \alpha_\mathrm{i} + \beta_{1,\mathrm{j}} * \mathrm{r_{m,t-1}} + \beta_{2,\mathrm{j}} * \mathrm{r_{i,t-1}} + \beta_{3,\mathrm{j}} * \mathrm{r_{m,t}} + \beta_{4,\mathrm{j}} * \mathrm{r_{i,t}} + \beta_{5,\mathrm{j}} * \mathrm{r_{m,t+1}} + \beta_{6,\mathrm{j}} * \mathrm{r_{i,t+1}} + \varepsilon_{\mathrm{j,t}} \quad (1)$$

where $r_{j,t}$ is the return on stock j in day t, $r_{m,t}$ is the return on the CRSP value weighted market index in day t, and $r_{i,t}$ is the return on the Fama-French 48 value-weighted industry indexes in day t.

The firm-specific daily return $R_{j,t}$ is the natural log of one plus the residual return from the regression (1) (i.e., $R_{j,t} = \ln(1 + \varepsilon_{\mathrm{j,t}})$). The rationale of why the raw residual returns is log-transformed is that the positive skew in the return distribution is weakened to ensure symmetry (Chen *et al*., 2001).

The negative skewness of firm-specific daily returns (NCSKEW) is the first firm-specific measure of stock price crash risk. For each firm-year, it refers to 'the negative of the third moment of each stock's firm-specific daily returns, divided by the cubed standard deviation' (Callen and Fang, 2015a, b). Therefore,

$$\text{NCSKEW}_{j,t} = \frac{-(n * (n-1)^{\frac{3}{2}} * \sum R_{j,t}^3)}{(n-1) * (n-2) * (\sum R_{j,t}^2)^{\frac{3}{2}}} \tag{2}$$

where n is the number of observations of firm-specific daily returns in year T. The denominator is a normalization factor (Greene, 1993). An increase of negative skewness (NCSKEW) indicates a more left-skewed return distribution and thus corresponds to a more 'crash-prone' stock (Chang *et al*., 2017).

The down-to-up volatility of firm-specific daily returns (DUVOL) is the second firm-specific measure of stock price crash risk (Fu *et al*., 2020). For each firm-year, it is defined as the natural logarithm transformation of the ratio of standard deviation of down days to that of up days. Thus,

$$\text{DUVOL}_{j,t} = \log\left\{\frac{\left[(n_u - 1) * \sum_{\text{DOWN}} R_{j,t}^2\right]}{\left[(n_d - 1) * \sum_{\text{UP}} R_{j,t}^2\right]}\right\} \tag{3}$$

where n_u (n_d) are the number of up (down) days in year t, respectively. The higher DUVOL indicates the more crash risk.

Crash dummy ($CRASH_{j,t}$) is the third firm-specific measure of stock price crash risk. For each firm-year, it equals to 1 if a firm experiences 1 or more crash days in a year, and 0, otherwise. Crash days are defined as those when a firm experiences firm-specific daily returns that are 3.09 standard deviations below the mean value of firm-specific daily returns in the same year (Hutton *et al*., 2009). The number 3.09 is used to generate the 0.1% cut-off of the normal distribution and is a benchmark to conveniently capture extreme returns (Callen and Fang, 2015a, b). Higher Crash implies that its corresponding stock is more 'crash-prone'.

9.2.3 Option Liquidity and Stock Price Crash Risk

After calculating option market liquidity and stock price crash risk, this study shifts lights to the effects of option liquidity on crash risk. Remarkably, it examines this relationship in the following regression:

$$CRASHRISK_{j,t} = \alpha + \beta_j OPTLIQ_{j,t-1} + \gamma Z_{j,t-1} + YR + IND + \phi_{j,t}$$

(4)

where subscription i and t indicates firm and year, respectively. $CRASHRISK_{j,t}$ is measured by one of $NCSKEW_{j,t}, DUVOL_{j,t}$ *and* $CRASH_{j,t}$. Option liquidity measures consist of the proportional bid-ask spread (*OBAS*), the natural logarithm of total option volume (*OVOL*) and the natural logarithm of total open interest (*OI*). $Z_{i,t-1}$ represents a vector of control variables. The selection of control variables follows the prior studies (Fang *et.al*, 2015; Chang *et al*., 2017; Huang and Mazouz, 2018), the control variables include firm size (*SIZE*), market-to-book ratio (*MB*), leverage (*LEV*), return on assets (*ROA*), financial opacity (*OPAQUE*), stock returns (*RET*), stock return volatility (*SIGMA*), stock turnover (*DTURN*) and stock proportional spread (*SBAS*). To avoid the endogeneity problem, this study shows the previous year details of the control variables in the regression. YR and IND are year and industry dummies based on the two-digit SIC code, respectively; and $\phi_{j,t}$ is a residual error term.

Following Kim *et al*. (2011b) and Chang *et al*. (2017), it is worthy of mentioning that we perform the OLS model where continuous variables, including negative skewness (NCKSEW) and the down-to-up volatility (DUVOL), are proxied as crash risk and performs logit regressions where dummy variable, crash dummy (CRASH) is the dependent variable. All models control for year and industry fixed effects. We also perform the regressions across all firms and use standard errors that are adjusted for double clustering by firm and year.

To further investigate how determining factors, including information asymmetry, investor sentiment, and short interest, reinforces the effects of option liquidity on stock price crash risk. Following the extant literature, this study uses the probability of informed trading (PIN) developed by Easley *et al*. (2002), insider trading developed by Ozkan and Ozkan (2004), short interest ratio constructed by Callen and Fang (2015) and put-to-call ratio chosen by Verousis *et al*. (2016b) to capture the degree of information asymmetry, the level of inventory risk, and the amount of cash holding, respectively. The higher probability of informed trading, short interest, investor sentiment, will induce the greater adverse selection cost, inventory costs, bearish emotion, and financial ability for firms. These drivers assist firms to exhibit less exposure to shocks to option market liquidity and attracts more investment. The increasing option liquidity, in turn, amplifies crash risk. It examines the role of these determinants in the following models:

$$CRASHRISK_{j,t} = \kappa_0 + \kappa_1 OPTLIQ_{j,t-1} * DETERMINANT_{i,t-1} + \kappa_2 * OPTLIQ_{j,t-1} + \kappa_3 * DETERMINANT_{i,t-1} + \gamma * X_{i,t-1} + YEAR + INDUSTRY + \nu_{i,t} \quad (5)$$

where subscription i and t indicates firm and year, respectively. $CRASHRISK_{j,t}$ is measured by one of $NCSKEW_{j,t}, DUVOL_{j,t}$ and $CRASH_{j,t}$. $OPTLIQ_{j,t}$ indicates option liquidity measures. Following the previous studies (e.g., Callen and Fang, 2015a, b; Liu and Zhong, 2018; Huang and Mazouz, 2018; Verousis *et al*., 2016b), $DETERMINANT_{i,t-1}$ includes short interest ratio, the probability of informed trading, insider trading, and investor sentiment. It performs the regressions in the whole sample period and adjust standard errors for clustering by firm and year.

9.3 Data

In this study, daily equity data is acquired from the Center for Research in Security Prices (CRSP) while equity option data comes from OptionMetrics. Daily closing prices, bid and ask prices, and the number of shares outstanding are gathered from the CRSP database. We also provide the stock identification number which allows this database to be merged with the option data.

Following An and Zhang (2013), our study focuses on publicly listed U.S. industrial firms and remove utility stocks (that is, companies with the Standard Industrial Classification (SIC) falling between 4900 and 4999). To avoid potential bias from the size effect, we analyse firms with market capitalization greater than 0.75 million dollars and stocks with share prices falling between $1 and $1000. We also exclude firms with negative assets and book value of equity to reduce the outlier effects (An and Zhang, 2013). Following Chan *et al.* (2013) and Kaul and Kayacetin (2017), we remove daily stock observations with prices smaller than $1 and greater than $999 or days without trades or closing stock price. Based on the above criteria, we have a sample size of 719 firms in its study.

Furthermore, we use the Compustat database which is provided by Capital *IQ* in the sample period. Using the stock identification number, we extract details related to the level of cash holding, book value of total assets, market value and book value of equity, long-term debt, income before extraordinary items, and the related financial opacity measures for the firms in the samples. In addition, we obtain insider trading details from the ISS Director data.

Our study obtains daily details about the call and put option prices, the strike prices, the option interest, volume and the expiry date from the equity option database. Observing the previous literature, we prepare the option data as follows: we exclude observations with zero trading volume or prices (Cao and Wei, 2010). Moneyness is defined as the option delta. Following previous studies (Chen *et al.,* 2011; Hayunga and Lung, 2014), we consider thin trading and remove options with the absolute value of delta smaller than 0.02 or greater than 0.98. Also, we remove financial options with maturity less than 3 days or longer than 90 days.

Table 9.1 displays the summary statistics of the firm characteristics and liquidity measures computed across 719 firms in our sample. The average of negative skewness (NCKSEW) is 0.56 and the standard deviation 2.81. The averages of the down-to-up volatility (DUVOL) and the crash dummy (CRASH) are 0.11 and 0.78, respectively. The averaged option spread is 0.15 ranging from 0.02 to 0.42. After multiplying by 0.1, the log of open interest is 1.45 and the log of option volume is 1.23. The stock spread is 0.17 percentage point.

Variable	No. Firms	Mean	Median	Std Dev	Max	Min
NCSKEW		0.56	0.04	2.81	15.65	-14.64
DUVOL		0.11	-0.04	1.21	8.08	-5.05
CRASH		0.78	1	0.42	1	0
OBAS		0.15	0.14	0.06	0.42	0.02
OI		1.45	1.45	0.18	2.00	0.92
OVOL		1.23	1.22	0.17	1.83	0.79
DTURN		-0.13	0.04	1.37	16.17	-12.55
SIGMA	719	0.27	0.24	0.14	1.18	0.06
RET		0.89	0.75	2.29	20.12	-9.51
SIZE		0.85	0.84	0.15	1.39	0.46
MB		0.60	0.31	8.04	560.31	0.01
LEV		0.17	0.15	0.15	0.80	0
ROA		0.15	0.14	0.10	0.73	-0.64
OPAQUE		0.17	0.12	0.24	7.63	0.002
SBAS		0.17	0.08	0.33	3.68	0.01
SENTIMENT		3.51	2.36	4.67	109.62	0.31
PIN	576	0.77	0.78	0.32	2.29	0
SHORTOUT	585	9.50	4.79	13.66	228.96	0.07
INSIDER	508	0.22	0.04	0.72	25.20	0

Notes: This table shows the descriptive statistics of stock price crash risks, option liquidity and other measures from 2000 to 2015. These measures are the yearly firm-level measures. Stock price crash risk measures are negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH). Option liquidity measures are: OBAS is yearly averaged option proportional bid-ask spread; OVOL is 0.1 times the log of option volume; OI is 0.1 times the log of open interest. Other measures are the detrended monthly stock turnover, stock SIGMA, stock return, firm size, market-to-book ratio, leverage, return on assets, financial opaqueness, stock proportional spread, the probability of informed trading, investor sentiment, short interest ratio and insider trading. SIGMA is 10 times stock SIGMA. RET is 1000 times stock return. MB is 0.1 times market-to-book ratio. SIZE is 0.1 times firm size. SBAS is 100 times stock proportional spread. PIN is 10*the probability of informed trading. As share outstanding is scaled by 1,000 in CRSP database, SHORTOUT is 1000 times short interest ratio and INSIDER is 1000 times insider trading. The values of option liquidity measures and other measures are lagged in one year. Their definitions and sources are reported in Appendix.

Table 9.1 Descriptive Statistics

Table 9.2 shows the Pearson correlation coefficients between the crash risk and option liquidity in this paper. As with the observations in Cao and Wei (2010), the option liquidity measures are highly correlated. That is, the correlation coefficients of option trading volume to the option proportional bid-ask spread and option interest are -0.80 and 0.99 respectively. Thus, option trading volume increases when the bid-ask spread decreases, or the open interest grows. Furthermore, crash risk measures are also highly correlated. In other words, the correlation coefficients of negative skewness (NCSKEW) to the down-to-up volatility (DUVOL) and the crash dummy (CRASH) are 0.92 and 0.48 respectively. Therefore, there is a close positive relationship among these three crash risk measures. Lastly, crash risk is positively correlated with option trading volume, open interest, but is negatively related to option proportional spread. These relationships are all significant at one percent level. Therefore, companies with higher option liquidity tend to observe a higher level of crash risk.

	NCSKEW	DUVOL	CRASH	OBAS	OI	OVOL
NCSKEW	1					
DUVOL	0.92 ***	1				
CRASH	0.48 ***	0.55 ***	1			
OBAS	-0.21 ***	-0.18 ***	-0.32 ***	1		
OI	0.15 ***	0.13 ***	0.34 ***	-0.77 ***	1	
OVOL	0.17 ***	0.14 ***	0.34 ***	-0.80 ***	0.99 ***	1

Notes: This table shows the unconditional, pair-wise correlations of crash risk measures, and option liquidity from 2000 to 2015. These measures are the yearly firm-level measures Stock price crash risk measures are negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH). Option liquidity measures are: OBAS is the log of the yearly averaged option proportional bid-ask spread; OVOL is the log of option volume; OI is the log of open interest. The values of option liquidity are lagged in one year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 9.2 Correlation Matrix of Crash Risk and Option Liquidity

Figure 9.1 illustrates the relationship between stock price crash risk and option market liquidity [54]. We compute the firm-level average of negative skewness (NCKSEW) and one-year lagged log of option proportional spread and classify firms into ten equal number groups depending on the level of spread. Then we sort them increasingly from Group 1 (bottom group) to Group 10 (top group) based on the level of option spread. We also take the average of the average negative skewness (NCKSEW) and option proportional spread for each group. The figure shows a monotonic relation between negative skewness (NCKSEW) and option proportional spread. We observe that option liquidity increases, i.e., the proportional bid-ask spread declines when the level of negative skewness (NCKSEW) increases. These results are in accordance with the

[54] The relations between crash measures such as negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH) and liquidity measures such as proportional spread, option interest and trading volume are qualitatively similar. We observe that three crash risk measures increase when option interest and trading volume increase and bid-ask spread decreases.

predictions that market crash increases in asset market liquidity (Bhatia *et al*., 2014; Chang *et al*. 2017).

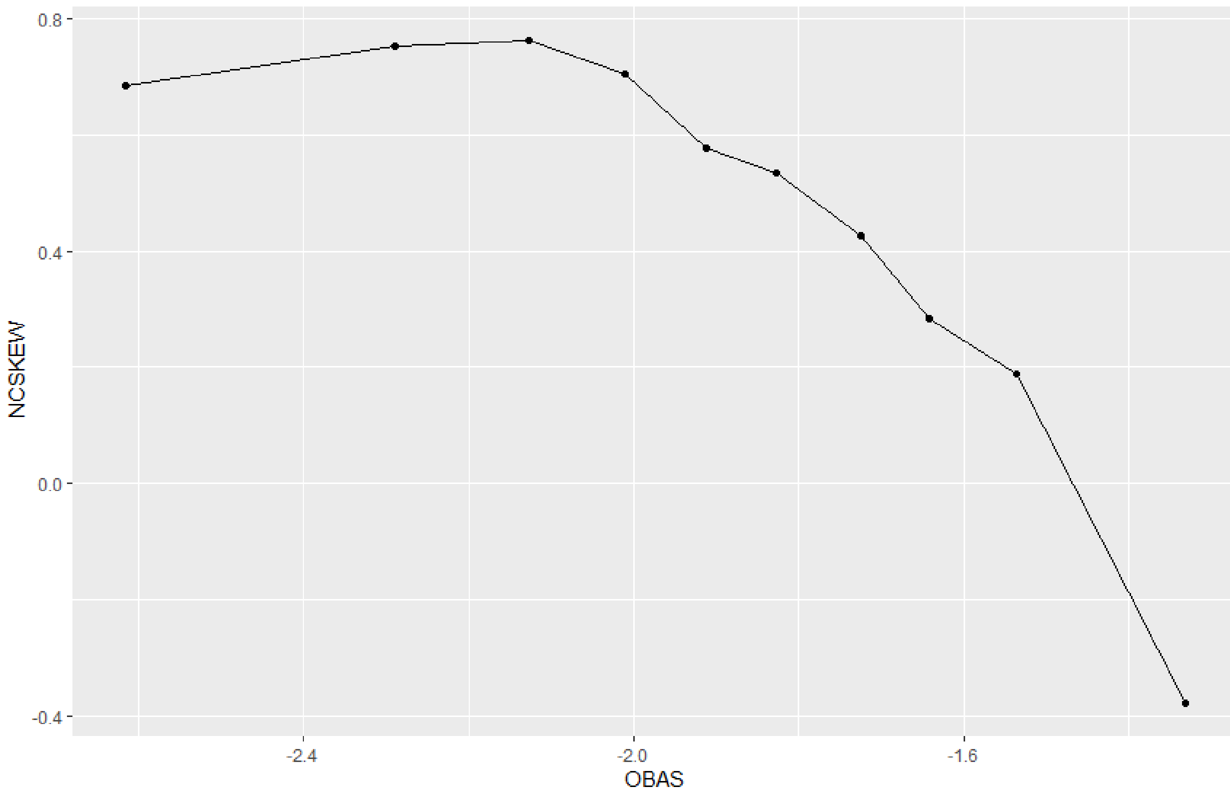


Figure 9.1 The Relationship between negative skewness (NCKSEW) and Option Proportional Spread

Notes: This figure presents the relationship between NCSKEW and the one-year lagged log of option proportional spread in (OBAS) from 2000 to 2015. We compute the firm-level average of negative skewness (NCSKEW)and option proportional spread and classify firms into ten equal number groups depending on the level of spread. Then we sort them increasingly from the Group 1 (bottom group) to Group 10 (top group) based on the level of option spread. We also take the average of the average NCSKEW and option proportional spread for each group.

9.4 Empirical Results

This study first presents the regression results to capture the effects of option liquidity on crash risk and then shows the robustness checks.

9.4.1 Option Liquidity and Stock Price Crash Risk

Table 9.3 reports the results from regression model (4) and demonstrates the role of option liquidity in illustrating crash risk [55]. Consistent with the argument in Chang *et al*. (2017), firms with option liquidity experience larger stock price crash risk. In Panel A, Column (1) shows the coefficients and t-statistics (in parentheses) from the regressions where negative skewness (NCKSEW) serves as the dependent variable. It observes that option proportional spread is significantly and negatively related to negative skewness (NCSKEW). An increase of 1% in option spread leads to a 0.68% reduction in negative skewness (NCSKEW) and the relation is significant at one percent level. In addition, the result suggests that stock spread is also significantly and negatively related to negative skewness (NCSKEW). An increase of 1% increase in stock spread leads to a 0.59% reduction in negative skewness (NCSKEW) and the relation is significant at one percent level.

In Panel A, Column (2) and Column (3) displays the results where option open interest and option trading volume serve as alternative measures of option liquidity in addition to option bid-ask spread. The results show that option open interest and trading volume is positively related to negative skewness (NCSKEW). They are consistent with the findings shown in Bhatia *et al*. (2014) that active option trading increases stock price crash.

Panel B and Panel C present similar patterns with the other two crash risk measures, the down-to-up volatility (DUVOL) and the crash dummy (CRASH). The results support our argument that option liquidity affects stock price crash risk. This evidence implies that firms with higher asset market liquidity are more likely to release negative information, along with greater selling by transient investors or the blockholder exists (Liu and Zhong, 2018; Edmans, 2009).

[55] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 1.76, indicating that our results are not significantly affected by multicollinearity problems.

Panel A: Negative Skewness (NCSKEW)

	OBAS	OI	OVOL
	(1)	(2)	(3)
OPTLIQ	-0.68 (-6.22) ***	0.61 (1.99) **	1.11 (3.37) ***
DTURN	-0.33 (-0.10)	-1.02 (-0.31)	-0.88 (-0.27)
SIGMA	-3.38 (-6.89) ***	-3.26 (-6.56) ***	-3.49 (-6.94) ***
RET	1.18 (7.03) ***	1.21 (7.05) ***	1.23 (7.21) ***
SIZE	-1.79 (-4.25) ***	-1.26 (-2.58) ***	-1.66 (-3.43) ***
MB	-0.27 (-0.19)	-0.48 (-0.33)	-0.65 (-0.47)
LEV	1.19 (0.40)	0.31 (0.10)	1.20 (0.39)
ROA	0.84 (1.62)	1.11 (2.14) **	1.01 (1.93) *
OPAQUE	0.30 (0.26)	0.60 (0.52)	0.38 (0.33)
SBAS	-0.59 (-3.90) ***	-0.73 (-4.82) ***	-0.69 (-4.56) ***
Constant	0.66 (0.97)	0.50 (0.72)	0.40 (0.58)
Observations	5087	5087	5087
R Squared	0.06	0.05	0.05
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel B: The Down-to-Up Volatility (DUVOL)

	OBAS	OI	OVOL
	(1)	(2)	(3)
OPTLIQ	-0.25 (-5.28) ***	0.14 (1.00)	0.35 (2.35) **
DTURN	0.16 (0.10)	-0.11 (-0.07)	-0.06 (-0.04)
SIGMA	-1.42 (-6.69) ***	-1.35 (-6.26)	-1.44 (-6.61) ***
RET	0.47 (6.06) ***	0.47 (6.01) ***	0.48 (6.17) ***
SIZE	-0.55 (-3.13) ***	-0.27 (-1.31)	-0.45 (-2.19) **
MB	0.54 (0.61)	0.50 (0.56)	0.43 (0.49)
LEV	0.80 (0.59)	0.32 (0.24)	0.70 (0.51)
ROA	0.59 (2.68) ***	0.70 (3.19) ***	0.66 (3.00) ***
OPAQUE	0.23 (0.44)	0.39 (0.73)	0.29 (0.56)
SBAS	-0.24 (-3.43) ***	-0.29 (-4.25) ***	-0.28 (-4.03) ***
Constant	0.06 (0.15)	0.05 (0.12)	-0.02 (-0.05)
Observations	5087	5087	5087
R Squared	0.06	0.05	0.06
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel C: Crash Dummy (CRASH)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ	-0.81 (-7.48) ***	2.74 (9.59) ***	3.06 (10.02) ***
DTURN	5.08 (1.75) *	4.93 (1.70) *	5.10 (1.74) *
SIGMA	-0.36 (-0.79)	-0.81 (-1.78) *	-1.11 (-2.43) **
RET	0.18 (1.03)	0.32 (1.85) *	0.33 (1.89) *
SIZE	-0.19 (-0.51)	-1.53 (-3.55) ***	-1.60 (-3.74) ***
MB	75.68 (1.30)	42.02 (1.26)	38.99 (1.29)
LEV	-2.10 (-0.76)	0.65 (0.23)	1.11 (0.39)
ROA	1.24 (2.94) ***	1.44 (3.28) ***	1.30 (2.97) ***
OPAQUE	-0.11 (-0.08)	-0.74 (-0.60)	-0.69 (-0.57)
SBAS	-0.20 (-1.29)	-0.27 (-1.75) *	-0.21 (-1.39)
Constant	-0.48 (-0.68)	-1.81 (-2.51) **	-1.53 (-2.14) **
Observations	5087	5087	5087
R Squared	0.06	0.06	0.06
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: This table shows for the coefficients and the t-statistics (in parentheses) of the regressions estimated over the sample period from 2000 to 2015. The dependent variables are 3 crash risk measures, negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH). Option liquidity measures are: OBAS is the log of option proportional bid-ask spread; OVOL is 0.1 times the log of option volume; OI is 0.1 times the log of open interest. OPTLIQ in the columns 1-3 represents OBAS, OI and OVOL, respectively. Other measures are the detrended monthly stock turnover, stock SIGMA, stock return, firm size, market-to-book ratio, leverage, return on assets, financial opaqueness, and stock proportional spread. Dturn is 0.01 times detrended monthly stock turnover. SIGMA is 10 times stock SIGMA. RET is 100 times stock return. MB is market-to-book ratio in basis point. Opaque is 0.1 times financial opaqueness. SIZE is 0.1 times firm size. Leverage is 0.1 times leverage. SBAS is 100 times stock proportional spread. The values of liquidity and other measures are lagged in one year. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables, respectively. The t-statistics are adjusted for clustering by firm and year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively. Their definitions and sources are reported in Appendix.

Table 9.3 Explaining Stock Price Crash Risk

9.4.2 Option Liquidity and Information Asymmetry

Having established the relation between option market liquidity and stock price crash risk, we use the degree of insider trading to capture the level of asymmetric information across firms. Ball (2006) shows that corporate insiders have superior ability to obtain private information about the firm fundamentals, so that insider trading might amplify asymmetric information problems, and therefore influence market liquidity. For these reasons, the following hypothesis will be tested:

H$_3$: Option liquidity further increases stock price crash risk in the firms with a high degree of information asymmetry.

Based on previous empirical studies (Ozkan and Ozkan, 2004), the degree of insider trading is proxied as the ratio of the total number of shares traded by insiders (namely, executive directors) and the total number of shares outstanding for firms.

Table 9.4 shows the results for model (5) that includes insider trading. The coefficient for the interaction term between option liquidity is negative when stock price crash risk is the dependent variable, and they are positive when option interest and volume serve as the liquidity measures [56]. These empirical results reconcile with the agency theoretical argument of Jin and Myers (2006) and Bhatia *et al*. (2014) which supposed that the asymmetries of information between corporate insiders and external shareholders can strengthen crash risk. Due to compensation maximization, employment protection and the reduction of litigation concerns arising from negative information disclosure, managers benefit from asymmetric information to cover bad news for a long time (Kothari *et al*., 2009). Agency problems cause information asymmetry and then cultivate large bad news hoarding. When accumulated negative information disseminates public at once, falling stock prices finally result in a crash. Thus, the severity of information asymmetry contributes to crash risk.

Furthermore, we observe the positive and significant impacts of insider trading on stock price crash risk. This is consistent with the negative information hoarding arguments that crash risk becomes greater in the degree of information asymmetry or insider trading (Hutton *et al*., 2009; Kothari *et al*., 2009). Firms incline to withhold bad information by stockpiling it for a long period. If bad news releases immediately, stock prices collapse in the end.

[56] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 2.17, indicating that our results are not significantly affected by multicollinearity problems.

Panel A: Negative Skewness (NCSKEW)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ*INSIDER	-0.83 (-3.29) ***	1.14 (1.65) *	1.21 (1.64)
OPTLIQ	-0.07 (-0.49)	0.47 (1.10)	0.68 (1.52)
INSIDER	0.37 (2.37) **	0.30 (1.74) *	0.29 (1.74) *
DTURN	6.11 (1.45)	4.52 (1.07)	4.74 (1.13)
SIGMA	-1.68 (-1.77) *	-1.67 (-1.78) *	-1.89 (-1.97)
RET	0.17 (0.56)	0.20 (0.67)	0.21 (0.69)
SIZE	-2.09 (-3.62) ***	-2.31 (-3.53) ***	-2.49 (-3.85) ***
MB	63.36 (3.15)	63.79 (3.04) ***	62.37 (3.07) ***
LEV	-0.48 (-0.11)	0.17 (0.04)	0.71 (0.17)
ROA	1.55 (2.35) **	1.47 (2.25) **	1.40 (2.14) **
OPAQUE	-3.77 (-0.70)	-3.90 (-0.72)	-4.50 (-0.83)
SBAS	-1.96 (-0.84)	-2.84 (-1.23)	-2.53 (-1.09)
Constant	-0.05 (-0.03)	0.21 (0.16)	0.35 (0.26)
Observations	2643	2643	2643
R Squared	0.05	0.05	0.05
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel B: The Down-to-Up Volatility (DUVOL)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ* INSIDER	-0.78 (-2.56) **	0.07 (0.24)	0.15 (0.35)
OPTLIQ	-0.10 (-0.72)	0.05 (0.34)	0.03 (0.17)
INSIDER	0.77 (2.92) ***	0.13 (0.58)	0.15 (1.00)
DTURN	3.50 (0.79)	2.63 (0.58)	2.90 (0.64)
SIGMA	-3.43 (-3.52) ***	-3.15 (-3.29) ***	-3.21 (-3.25)
RET	0.11 (0.37)	0.11 (0.35)	0.09 (0.31)
SIZE	-2.03 (-3.58) ***	-1.67 (-3.22) ***	-1.69 (-2.79) ***
MB	62.00 (3.02) ***	64.66 (2.86) ***	65.47 (2.89) ***
LEV	-1.11 (-0.26)	-1.91 (-0.45)	-2.10 (-0.49)
ROA	0.77 (1.17)	0.86 (1.32)	0.86 (1.30)
OPAQUE	-6.59 (-1.20)	-4.88 (-0.90)	-4.70 (-0.88)
SBAS	0.08 (0.04)	-0.73 (-0.33)	-0.72 (-0.33)
Constant	0.68 (0.50)	0.29 (0.24)	0.39 (0.30)
Observations	2643	2643	2643
R Squared	0.05	0.05	0.05
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel C: Crash Dummy (CRASH)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ* INSIDER	-0.53 (-1.65) *	1.20 (1.46)	1.50 (1.65) *
OPTLIQ	-0.39 (-2.55) **	2.05 (4.44) ***	2.14 (4.37) ***
INSIDER	0.01 (0.07)	0.06 (0.26)	0.09 (0.40)
DTURN	11.64 (2.66) ***	9.72 (2.21) **	10.28 (2.29) **
SIGMA	0.94 (1.12)	0.79 (0.95)	0.43 (0.52)
RET	-0.08 (-0.26)	0.09 (0.31)	0.09 (0.30)
SIZE	0.04 (0.06)	-1.24 (-1.82) *	-1.21 (-1.78) *
MB	80.03 (1.07)	57.18 (1.09)	54.85 (1.12)
LEV	-9.76 (-2.25) **	-6.36 (-1.45)	-6.02 (-1.37)
ROA	0.98 (1.50)	0.79 (1.17)	0.73 (1.09)
OPAQUE	1.26 (0.25)	-2.52 (-0.50)	-2.54 (-0.51)
SBAS	-3.99 (-1.98) **	-5.33 (-2.69)	-4.64 (-2.34) **
Constant	2.37 (1.90) *	3.32 (2.47) **	3.22 (2.39) **
Observations	2643	2643	2643
R Squared	0.07	0.08	0.08
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: This table shows for the coefficients and the *t*-statistics (in parentheses) of the regressions estimated over the sample period from 2008 to 2015. The dependent variables are 3 crash risk measures, negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH). Option liquidity measures are: OBAS is the log of yearly averaged option proportional bid-ask spread; OVOL is 0.1 times the log of option volume; OI is 0.1 times the log of open interest. OPTLIQ in the columns 1-3 represents OBAS, OI and OVOL, respectively. Other measures are the detrended monthly stock turnover, stock SIGMA, stock return, firm size, market-to-book ratio, leverage, return on assets, stock proportional spread and insider trading. The values of liquidity and other measures are lagged in one year. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables, respectively. The *t*-statistics are adjusted for clustering by firm and year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively. Their definitions and sources are reported in Appendix.

Table 9.4 Insider Trading and Option Liquidity in Determining Crash Risk

In addition to insider trading, we examine the joint effects of information asymmetry and option liquidity in explaining crash risk. Reflecting the information asymmetry problem, we use a probability of informed trading (PIN). A higher PIN implies a higher degree of information asymmetry (Duarte and Young, 2009). Therefore, we concentrate on the joint interaction between option liquidity and information asymmetry and expect that information asymmetry will reinforce the role of option liquidity on crash risk.

Table 9.5 presents the results of the regressions (equation 5) including the probability of informed trading [57]. Panel A shows the results where negative skewness (NCKSEW) serves as the dependent variable. In column 1, the coefficient of option spread remains negative and significant as shown in Table 3. The coefficient of the interaction term between the probability of informed trading (PIN) and option spread is negative and significant. Consistent with short-termism theory and governance theory (blockholder exit mechanism), this finding suggests that option liquidity attracts a large amount of irrational investment from transient investors and benefits blockholders to withdraw. If the accumulated bad news is made public at once, "cutting-and running" selling by transient investors and the exists of blockholders amplify stock price crash risk, especially in firms with a higher degree of information-driven trading (Bhatia *et al*., 2014; Edmans, 2009).

Similar findings are also observed in Column (2) and Column (3) of Table 4 where option open interest and trading volume are used as the option liquidity measures. The coefficients of the interaction terms between the probability of informed trading and these two liquidity measures are all positive and significant. Furthermore, Panel B and Panel C present similar patterns with the other two crash risk measures, the down-to-up volatility (DUVOL) and the crash dummy (CRASH). The evidence indicates that stock price crash risk is greater in firms with higher option liquidity, especially for firms with a higher level of probability of informed trading.

[57] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 1.84, indicating that our results are not significantly affected by multicollinearity problems.

Panel A: Negative Skewness (NCSKEW)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ*PIN	-6.05 (-1.63)	7.45 (0.81)	10.73 (1.14)
OPTLIQ	-0.96 (-5.24) ***	1.49 (3.53) ***	2.00 (4.50) ***
PIN	7.54 (3.30) ***	5.87 (2.55) ***	6.96 (3.09) ***
DTURN	1.64 (0.46)	2.44 (0.70)	2.48 (0.71)
SIGMA	-4.89 (-7.17) ***	-5.04 (-7.27) ***	-5.27 (-7.48) ***
RET	1.16 (5.35) ***	1.23 (5.58) ***	1.24 (5.64) ***
SIZE	-2.39 (-4.87) ***	-3.08 (-5.44) ***	-3.26 (-5.88) ***
MB	-2.85 (-1.33)	-3.74 (-1.76) *	-3.81 (-1.78) *
LEV	1.30 (0.33)	2.82 (0.71)	3.30 (0.83)
ROA	-0.12 (-0.18)	0.28 (0.47)	0.19 (0.32)
OPAQUE	1.30 (0.76)	1.05 (0.61)	1.01 (0.59)
SBAS	-0.11 (-0.61)	-0.19 (-1.08)	-0.18 (-0.99)
Constant	2.85 (3.12) ***	3.24 (3.38) ***	3.49 (3.61) ***
Observations	2813	2813	2813
R Squared	0.11	0.10	0.11
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel B: The Down-to-Up Volatility (DUVOL)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ*PIN	-5.20 (-1.40)	13.53 (1.48)	16.53 (1.75) *
OPTLIQ	-0.85 (-4.75) ***	0.88 (2.19) ***	1.42 (3.31) ***
PIN	7.42 (3.25) ***	6.34 (2.76) ***	7.33 (3.22) ***
DTURN	-0.03 (-0.01)	0.50 (0.14)	0.60 (0.17)
SIGMA	-4.53 (-6.68) ***	-4.55 (-6.68) ***	-4.74 (-6.85) ***
RET	1.10 (5.15) ***	1.16 (5.37) ***	1.18 (5.45) ***
SIZE	-2.08 (-4.23) ***	-2.36 (-4.19) ***	-2.61 (-4.72) ***
MB	-3.11 (-1.44)	-3.68 (-1.73) *	-3.81 (-1.77) *
LEV	-2.63 (-0.67)	-1.97 (-0.50)	-1.39 (-0.35)
ROA	0.19 (0.31)	0.56 (0.96)	0.48 (0.82)
OPAQUE	1.31 (0.77)	1.22 (0.69)	1.15 (0.66)
SBAS	-0.22 (-1.24)	-0.28 (-1.62)	-0.28 (-1.58)
Constant	2.77 (3.11) ***	2.75 (2.96) ***	3.06 (3.29) ***
Observations	2813	2813	2813
R Squared	0.10	0.10	0.10
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel C: Crash Dummy (CRASH)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ*PIN	-15.08 (-3.73) ***	31.99 (3.50) ***	38.74 (4.09) ***
OPTLIQ	-1.03 (-4.98) ***	2.42 (5.37) ***	2.88 (6.03) ***
PIN	7.33 (2.76) ***	7.64 (2.87) ***	8.76 (3.34) ***
DTURN	3.41 (1.01)	4.11 (1.25)	4.10 (1.23)
SIGMA	-0.15 (-0.27)	-0.31 (-0.55)	-0.53 (-0.94)
RET	0.59 (2.64) ***	0.70 (3.16) ***	0.70 (3.17) ***
SIZE	0.51 (0.98)	-0.70 (-1.17)	-0.73 (-1.24)
MB	124.32 (0.81)	78.19 (0.54)	66.46 (0.47)
LEV	-3.89 (-0.98)	-2.02 (-0.51)	-1.72 (-0.43)
ROA	1.39 (2.06) **	1.96 (2.87) ***	1.85 (2.69) ***
OPAQUE	0.59 (0.34)	0.26 (0.18)	0.37 (0.25)
SBAS	-0.11 (-0.68)	-0.15 (-0.85)	-0.11 (-0.67)
Constant	1.90 (1.52)	2.79 (2.23) **	2.90 (2.31) **
Observations	2813	2813	2813
R Squared	0.07	0.07	0.07
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: This table shows for the coefficients and the t-statistics (in parentheses) of the regressions estimated over the sample period from 2000 to 2010. The dependent variables are 3 crash risk measures, negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH). Option liquidity measures are: OBAS is the log of yearly averaged option proportional bid-ask spread; OVOL is 0.1 times the log of option volume; OI is 0.1 times the log of open interest. OPTLIQ in the columns 1-3 represents OBAS, OI and OVOL, respectively. Other measures are the detrended monthly stock turnover, stock SIGMA, stock return, firm size, market-to-book ratio, leverage, return on assets, stock proportional spread and PIN. The values of liquidity and other measures are lagged in one year. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables, respectively. The *t*-statistics are adjusted for clustering by firm and year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively. Their definitions and sources are reported in Appendix.

Table 9.5 Information Asymmetry and Option Liquidity in Determining Crash Risk

9.4.3 Option Liquidity and Short Interest

Having established the relation between option market liquidity and stock price crash risk, we explore the joint effect of short interest and option liquidity on crash risk. Short sellers are assumed to be sophisticated traders who can detect managerial bad news hoarding activities and thereby anticipate crash risk by shorting stocks (Callen and Fang, 2015b). To reflect the likelihood for the firms' bad news hoarding activities, we use the short interest ratio, measured as ‘the number of shares sold short divided by total shares outstanding from the last month of the fiscal year’ (Callen and Fang, 2015b). A higher short interest ratio indicates a higher likelihood of negative information hoarding behaviour. Therefore, we focus on the joint interaction between option liquidity and short interest and expects that short-sale constraints will reinforce the role of option liquidity on crash risk. For these reasons, the following hypothesis will be tested:

H_4: Option liquidity further increases stock price crash risk in the firms with a large level of short interests.

Table 9.6 presents the results of the regressions (equation 5) related to the short interest ratio. Panel A shows the results where negative skewness (NCKSEW) serves as the dependent variable [58]. In column 1, the coefficient of option spread remains negative and significant as shown in Table 3. The coefficient of the interaction term between short interest (SHORT) and option spread is negative and significant. This result suggests that among groups of firms with larger short interest, the contribution of the option liquidity is the most significant and determines crash risk primarily. It is in accordance with the firm’s agency conflicts and governance mechanisms proposed by Callen and Fang (2013, 2015b). The existence of agency conflicts between managers and shareholders leads to the managerial bad news hoarding activities (Hutton *et al*., 2009). Its severity is useful for short sellers to identify the firms which withhold bad news. Furthermore, weaker external monitoring mechanisms exacerbate agency conflict problems and force managers to cover negative information. Therefore, short sellers anticipate crash risk by uncovering bad news hoarding behaviour of managers, which prompts them to short stocks.

Similar findings are also observed in Column (2) and Column (3) of Table 6 where option open interest and trading volume are used as the option liquidity measures. The coefficients of the interaction terms between short interest and these two liquidity measures are all positive and significant. Furthermore, Panel B and Panel C present similar patterns with the other two crash risk measures, the down-to-up volatility (DUVOL) and the crash dummy (CRASH). The

[58] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 2.64, indicating that our results are not significantly affected by multicollinearity problems.

evidence indicates that stock price crash risk is greater in firms with higher option liquidity, especially for firms with larger short interest.

In addition to the interaction terms, we observe a positive and significant impact of the short interest on stock price crash risk. The evidence indicates that for firms that suffer more from short-selling constraints, option market liquidity amplifies crash risk.

Panel A: Negative Skewness (NCSKEW)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ*SHORT	-2.23 (-2.33) **	0.47 (0.52)	1.48 (1.61)
OPTLIQ	-1.12 (-6.03) ***	0.71 (3.29) ***	0.66 (3.47) ***
SHORT	2.40 (2.95) ***	0.96 (1.27)	0.42 (0.61)
DTURN	-7.06 (-0.94)	-8.49 (-1.13)	-8.60 (-1.15)
SIGMA	-6.00 (-4.75) ***	-5.88 (-4.67) ***	-6.12 (-4.85) ***
RET	0.99 (2.44) **	1.05 (2.61) ***	1.05 (2.62) ***
SIZE	-2.71 (-4.01) ***	-2.15 (-3.44) ***	-2.30 (-3.52) ***
MB	18.30 (0.85)	14.62 (0.73)	13.13 (0.62)
LEV	5.74 (1.11)	3.75 (0.74)	4.72 (0.93)
ROA	-0.40 (-0.51)	0.12 (0.16)	0.01 (0.01)
OPAQUE	-6.24 (-0.97)	-4.52 (-0.74)	-5.22 (-0.84)
SBAS	-0.14 (-0.29)	-0.31 (-0.57)	-0.32 (-0.60)
Constant	1.50 (1.09)	-0.34 (-0.26)	0.01 (0.01)
Observations	3973	3973	3973
R Squared	0.04	0.03	0.03
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel B: The Down-to-Up Volatility (DUVOL)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ* SHORT	-2.48 (-2.64) ***	1.61 (1.73) *	2.39 (2.52) **
OPTLIQ	-1.18 (-6.37) ***	0.42 (2.13) **	0.46 (2.40) **
SHORT	3.21 (3.77) ***	0.43 (0.57)	0.38 (0.59)
DTURN	-2.56 (-0.35)	-4.93 (-0.65)	-4.58 (-0.60)
SIGMA	-5.70 (-4.77) ***	-5.44 (-4.57) ***	-5.58 (-4.62) ***
RET	0.61 (1.57)	0.61 (1.61)	0.60 (1.60)
SIZE	-2.37 (-3.52) ***	-1.58 (-2.50) **	-1.55 (-2.35) **
MB	50.09 (2.85) ***	47.95 (2.64) ***	46.84 (2.64) ***
LEV	7.98 (1.59)	5.15 (1.04)	5.54 (1.11)
ROA	-0.40 (-0.52)	0.12 (0.15)	0.10 (0.12)
OPAQUE	-4.89 (-0.79)	-2.16 (-0.37)	-2.34 (-0.40)
SBAS	-0.14 (-0.26)	-0.38 (-0.64)	-0.38 (-0.64)
Constant	0.75 (0.55)	-1.06 (-0.80)	-1.01 (-0.76)
Observations	3973	3973	3973
R Squared	0.04	0.03	0.03
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel C: Crash Dummy (CRASH)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ* SHORT	-0.34 (-1.67) *	0.23 (1.03)	0.22 (1.06)
OPTLIQ	-0.33 (-1.84) *	0.42 (1.99) **	0.43 (2.25) **
SHORT	0.31 (1.89) *	0.07 (0.32)	0.07 (0.41)
DTURN	5.01 (1.30)	4.57 (1.17)	4.41 (1.13)
SIGMA	0.01 (0.01)	-0.22 (-0.37)	-0.33 (-0.55)
RET	-0.15 (-0.69)	-0.07 (-0.30)	-0.08 (-0.35)
SIZE	0.78 (1.59)	0.53 (1.04)	0.50 (0.97)
MB	101.27 (1.23)	96.04 (1.19)	103.87 (1.25)
LEV	-5.23 (-1.55)	-5.08 (-1.49)	-4.72 (-1.38)
ROA	1.51 (3.04) ***	1.68 (3.37)	1.63 (3.24) ***
OPAQUE	2.85 (0.73)	0.95 (0.24)	0.96 (0.24)
SBAS	-0.03 (-0.11)	-0.12 (-0.44)	-0.10 (-0.38)
Constant	0.28 (0.34)	-0.07 (-0.08)	-0.05 (-0.06)
Observations	3973	3973	3973
R Squared	0.05	0.05	0.05
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: This table shows for the coefficients and the *t*-statistics (in parentheses) of the regressions estimated over the sample period from 2000 to 2015. The dependent variables are 3 crash risk measures, negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH). Option liquidity measures are: OBAS is the log of yearly averaged option proportional bid-ask spread; OVOL is 0.1 times the log of option volume; OI is 0.1 times the log of open interest. OPTLIQ in the columns 1-3 represents OBAS, OI and OVOL, respectively. Other measures are the detrended monthly stock turnover, stock SIGMA, stock return, firm size, market-to-book ratio, leverage, return on assets, stock proportional spread and short interest. The values of liquidity and other measures are lagged in one year. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables, respectively. The *t*-statistics are adjusted for clustering by firm and year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively. Their definitions and sources are reported in Appendix.

Table 9.6 Short Interest and Option Liquidity in Determining Crash Risk

9.4.4 Option Liquidity and Investor Sentiment

Having established the relation between option market liquidity and stock price crash risk, we analyse the joint effect of option trader sentiment and option liquidity on crash risk. To reflect the informational content for future stock price movements, sentiment is proxied as the ratio of put-to-call traded volume (Pan and Poteshman, 2006). A higher put-call ratio implies that more put options being bought relative to call options. Option traders have a higher likelihood to anticipate falling asset prices (Verousis *et al*., 2016b). Therefore, we concentrate on the joint interaction between option liquidity and option trader sentiment and expects that sentiment will reinforce the role of option liquidity on crash risk. For these reasons, the following hypothesis will be tested:

H_5: Option liquidity further increases stock price crash risk in the firms with high option trader sentiment.

Table 9.7 presents the results of the regressions (equation 5) including investor sentiment. [59] Panel A shows the results where negative skewness (NCKSEW) serves as the dependent variable. In column 1, the coefficient of option spread remains negative and significant as shown in Table 3. The coefficient of the interaction term between the put-call ratio (*Sentiment*) and option liquidity is negative and significant. This result suggests that among groups of firms with larger put-call ratio, option liquidity matters even more and determines crash risk. It is consistent with the argument proposed by Figlewski (1989), arbitrageurs can sell the stock short or buy

[59] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 2.05, indicating that our results are not significantly affected by multicollinearity problems.

more puts relative to calls, so option trader sentiment is one of rational arbitrageur sentiment. However, due to noise risk, the stock price cannot fully capture the information, particularly for negative information, which limits option traders' arbitrage positions (De Long *et al*., 1990). Furthermore, managers purposely withhold bad news when option trading is active, especially during high option trader sentiment periods (Jin and Myers, 2006). Hence, option trader sentiment significantly affects stock price crash (Fu *et al*., 2020).

Similar results are also observed in Column (2) and Column (3) of Table 7 where option open interest and trading volume are used as the option liquidity measures. The coefficients of the interaction terms between option trader sentiment and option liquidity are all positive and significant. Furthermore, Panel B and Panel C present similar patterns with the other two crash risk measures, the down-to-up volatility (DUVOL) and the crash dummy (CRASH). The evidence indicates that for stock price crash risk is more significant in firms with higher option liquidity, especially for firms with high option trader sentiment.

In addition to the interaction terms, we observe a positive and significant impact of option trader sentiment on stock price crash risk. The evidence indicates that for firms with high option trader sentiment, option market liquidity amplifies crash risk.

Panel A: Negative Skewness (NCSKEW)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ* SENTIMENT	-1.10 (-3.19) ***	1.64 (2.35) **	1.97 (2.40) **
OPTLIQ	-0.61 (-5.28) ***	0.40 (1.17)	0.95 (2.63) ***
SENTIMENT	0.33 (2.54) **	0.36 (2.03) **	0.45 (2.38) **
DTURN	-0.82 (-0.25)	-1.41 (-0.43)	-1.43 (-0.43)
SIGMA	-3.13 (-6.35) ***	-3.16 (-6.32) ***	-3.39 (-6.70) ***
RET	1.17 (7.02) ***	1.22 (7.13) ***	1.24 (7.28) ***
SIZE	-1.58 (-3.74) ***	-1.10 (-2.22) **	-1.51 (-3.10) ***
MB	-0.20 (-0.14)	-0.53 (-0.36)	-0.67 (-0.48)
LEV	0.67 (0.22)	-0.001 (0)	0.93 (0.30)
ROA	0.88 (1.69) *	1.17 (2.25) **	1.08 (2.06) **
OPAQUE	0.54 (0.47)	0.66 (0.56)	0.46 (0.40)
SBAS	-0.58 (-3.83) ***	-0.73 (-4.85) ***	-0.69 (-4.57) ***
Constant	1.74 (2.43) **	1.23 (1.66) *	1.64 (2.21) **
Observations	5087	5087	5087
R Squared	0.06	0.05	0.05
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel B: The Down-to-Up Volatility (DUVOL)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ* SENTIMENT	-0.48 (-3.18) ***	0.67 (2.04) **	0.85 (2.24) **
OPTLIQ	-0.22 (-4.36) ***	0.04 (0.26)	0.27 (1.65) *
SENTIMENT	0.13 (2.48) **	0.13 (1.78) *	0.18 (2.26) **
DTURN	-0.03 (-0.02)	-0.24 (-0.16)	-0.26 (-0.17)
SIGMA	-1.31 (-6.18) ***	-1.31 (-6.05) ***	-1.39 (-6.39) ***
RET	0.47 (6.06) ***	0.48 (6.09) ***	0.49 (6.24) ***
SIZE	-0.46 (-2.62) ***	-0.21 (-0.99)	-0.39 (-1.88) *
MB	0.56 (0.63)	0.47 (0.52)	0.41 (0.47)
LEV	0.59 (0.43)	0.19 (0.14)	0.58 (0.42)
ROA	0.60 (2.76) ***	0.72 (3.28) ***	0.69 (3.13) ***
OPAQUE	0.33 (0.62)	0.41 (0.76)	0.32 (0.61)
SBAS	-0.23 (-3.37) ***	-0.29 (-4.29) ***	-0.28 (-4.05) ***
Constant	0.44 (1.17)	0.18 (0.46)	0.35 (0.92)
Observations	5087	5087	5087
R Squared	0.06	0.05	0.06
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel C: Crash Dummy (CRASH)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ* SENTIMENT	-1.04 (-4.05) ***	2.26 (3.66) ***	3.09 (4.35) ***
OPTLIQ	-0.55 (-4.47) ***	2.09 (5.89) ***	2.34 (6.41) ***
SENTIMENT	0.30 (2.06) **	0.19 (1.67) *	0.27 (2.36) **
DTURN	5.28 (1.83) *	4.47 (1.55)	4.41 (1.50)
SIGMA	-0.25 (-0.54)	-0.65 (-1.41)	-0.93 (-2.01) **
RET	0.20 (1.14)	0.34 (1.97) **	0.35 (2.03) **
SIZE	-0.10 (-0.26)	-1.20 (-2.76) ***	-1.27 (-2.98) ***
MB	71.02 (1.31)	45.66 (1.24)	42.24 (1.28)
LEV	-2.22 (-0.79)	0.003 (0)	0.47 (0.16)
ROA	1.29 (3.03) ***	1.54 (3.56) ***	1.45 (3.34) ***
OPAQUE	-0.14 (-0.10)	-0.70 (-0.57)	-0.67 (-0.55)
SBAS	-0.20 (-1.29)	-0.28 (-1.79) *	-0.23 (-1.44)
Constant	1.17 (1.62)	1.79 (2.41) **	1.83 (2.48) **
Observations	5087	5087	5087
R Squared	0.06	0.06	0.07
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: This table shows for the coefficients and the t-statistics (in parentheses) of the regressions estimated over the sample period from 2000 to 2015. The dependent variables are 3 crash risk measures, negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH). Option liquidity measures are: OBAS is the log of option proportional bid-ask spread; OVOL is 0.1 times the log of option volume; OI is 0.1 times the log of open interest. OPTLIQ in the columns 1-3 represents OBAS, OI and OVOL, respectively. Other measures are the detrended monthly stock turnover, stock SIGMA, stock return, firm size, market-to-book ratio, leverage, return on assets, financial opaqueness, option trader sentiment and stock proportional spread. Dturn is 0.01 times detrended monthly stock turnover. SIGMA is 10 times stock SIGMA. RET is 100 times stock return. MB is market-to-book ratio in basis point. Opaque is 0.1 times financial opaqueness. SIZE is 0.1 times firm size. Leverage is 0.1 times leverage. SBAS is 100 times stock proportional spread. The values of liquidity and other measures are lagged in one year. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables, respectively. The t-statistics are adjusted for clustering by firm and year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively. Their definitions and sources are reported in Appendix.

Table 9.7 Investor Sentiment and Option Liquidity in Determining Crash Risk

9.5 Robust Check

We first show the findings from the models controlling for the different weighting average schemes for option proportional spread and different option moneyness. We then consider the sensitivities of our findings with a highly volatile period and ultimately use endogeneity analysis.

9.5.1 Controlling for Different Weighting Average Schemes

As discussed in the data part, we use an equal weighting average scheme to obtain the option proportional bid-ask spread for a stock across all individual option contracts of the same underlying. In this analysis, we assess the sensitivities of our results in different weighting average schemes for option spread. We obtain the option volume-weighted average and the option interest-weighted average of the option spread for common stocks on a daily basis. For brevity, we display the findings of the regression (4) with the option spread obtained from these two weighting average schemes.

Table 9.8 demonstrates the effects of option liquidity on stock price crash risk [60]. As with the results in Table (3), we observe significant effects of option spread on stock price crash risk. Option spread registers negative and significant coefficients to crash risk obtained from both weighting schemes. In line with the predictions in Chang *et al*. (2017), the findings indicate that option market liquidity significantly explains the variations in crash risk.

[60] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 1.62, indicating that our results are not significantly affected by multicollinearity problems.

Panel A: OIWOBAS

	NCSKEW	DUVOL	CRASH
	(1)	(2)	(3)
OPTLIQ	-2.97 (-2.39) **	-1.07 (-1.62)	-1.68 (-4.99) ***
DTURN	-1.30 (-0.39)	-0.20 (-0.13)	0.65 (1.45)
SIGMA	-3.06 (-6.31) ***	-1.30 (-6.18) ***	-0.02 (-0.25)
RET	1.20 (7.04) ***	0.48 (6.07) ***	0.05 (1.53)
SIZE	-0.94 (-2.44) **	-0.24 (-1.40)	0.02 (0.27)
MB	-0.41 (-0.28)	0.49 (0.55)	0.86 (3.70) ***
LEV	-0.38 (-0.13)	0.22 (0.16)	-0.37 (-0.79)
ROA	1.18 (2.31) **	0.71 (3.30) ***	0.29 (4.12) ***
OPAQUE	0.73 (0.62)	0.39 (0.73)	-0.01 (-0.06)
SBAS	-0.74 (-4.91) ***	-0.29 (-4.25) ***	-0.06 (-2.17) **
Constant	1.22 (1.74) *	0.26 (0.68)	0.73 (6.25) ***
Observations	5087	5087	5087
R Squared	0.05	0.05	0.06
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel B: VOLWOBAS

	NCSKEW	DUVOL	CRASH
	(1)	(2)	(3)
OPTLIQ	-0.53 (-4.48) ***	-0.18 (-3.02) ***	-0.19 (-8.97) ***
DTURN	-0.99 (-0.30)	-0.09 (-0.06)	0.80 (1.76) *
SIGMA	-3.27 (-6.68) ***	-1.37 (-6.47) ***	-0.10 (-1.28)
RET	1.23 (7.22) ***	0.49 (6.19) ***	0.05 (1.68) *
SIZE	-1.37 (-3.38) ***	-0.38 (-2.13) **	-0.09 (-1.48)
MB	-0.60 (-0.43)	0.43 (0.50)	0.83 (3.99) ***
LEV	0.38 (0.13)	0.47 (0.35)	-0.18 (-0.38)
ROA	1.09 (2.12) ***	0.68 (3.14) ***	0.26 (3.63) ***
OPAQUE	0.41 (0.36)	0.29 (0.54)	-0.08 (-0.33)
SBAS	-0.70 (-4.66) ***	-0.28 (-4.07) ***	-0.05 (-1.80) *
Constant	1.77 (2.49) **	0.44 (1.15)	0.85 (7.66) ***
Observations	5087	5087	5087
R Squared	0.06	0.06	0.06
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: This table shows for the coefficients and the t-statistics (in parentheses) of the regressions estimated over the sample period from 2000 to 2015. The dependent variables are 3 crash risk measures, negative skewness

(NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH). Option liquidity measures are option volume-weighted average and the option interest-weighted average of the option spread. OIWBAS is 100 times option open interest-weighted average of option spread. VOLWOBAS is 100 times option volume-weighted average of option spread. Other measures are the detrended monthly stock turnover, stock SIGMA, stock return, firm size, market-to-book ratio, leverage, return on assets, financial opaqueness, and stock proportional spread. Dturn is 0.01 times detrended monthly stock turnover. SIGMA is 10 times stock SIGMA. RET is 100 times stock return. MB is market-to-book ratio in basis point. Opaque is 0.1 times financial opaqueness. SIZE is 0.1 times firm size. Leverage is 0.1 times leverage. SBAS is 100 times stock proportional spread. The values of liquidity and other measures are lagged in one year. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables, respectively. The t-statistics are adjusted for clustering by firm and year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively. Their definitions and sources are reported in Appendix.

Table 9.8 Different Weighting Average Schemes

9.5.2 Controlling for Option Moneyness

As discussed in the data part, we select individual option contracts with a given moneyness (delta). In this analysis, we assess the sensitivities of our results in different moneyness schemes for option spread. We obtain the at-the-moneyness (ATM) option spread for common stocks which absolute value of moneyness ranges from 0.4 to 0.6 on a daily basis (Chen *et al*., 2011). For brevity, we display the findings of regression (4) with the ATM option spread.

Table 9.9 demonstrates the effects of ATM option liquidity on stock price crash risk [61]. Similar to the results in Table (3), we observe significant effects of ATM option liquidity on stock price crash risk. In line with the predictions in Chang *et al*. (2017), the findings indicate that option market liquidity significantly explains the variations in crash risk.

[61] We perform variance inflation factor (VIF) analysis to examine the effects of multicollinearity in the regressions. The average of the results from the VIF analysis of the independent variables in the regressions is 1.84, indicating that our results are not significantly affected by multicollinearity problems.

Panel A: Negative Skewness (NCSKEW)

	OBAS	OI	OVOL
	(1)	(2)	(3)
OPTLIQ	-0.57 (-5.01) ***	0.21 (0.43)	1.21 (2.40) **
DTURN	-2.82 (-0.62)	-2.98 (-0.65)	-2.99 (-0.66)
SIGMA	-3.05 (-4.52) ***	-2.79 (-4.11) ***	-3.17 (-4.60) ***
RET	0.80 (3.92) ***	0.89 (4.28) ***	0.86 (4.17) ***
SIZE	-2.00 (-3.59) ***	-0.87 (-1.44)	-1.59 (-2.67) ***
MB	37.11 (1.17)	34.88 (1.13)	35.76 (1.13)
LEV	2.23 (0.54)	-0.06 (-0.01)	1.27 (0.31)
ROA	0.51 (0.80)	0.90 (1.41)	0.79 (1.24)
OPAQUE	2.48 (0.84)	3.80 (1.27)	2.76 (0.93)
SBAS	-0.44 (-1.95) *	-0.59 (-2.62) ***	-0.55 (-2.46) **
Constant	1.03 (1.59)	0.88 (1.22)	0.49 (0.72)
Observations	3076	3076	3076
R Squared	0.07	0.07	0.07
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel B: The Down-to-Up Volatility (DUVOL)

	OBAS	OI	OVOL
	(1)	(2)	(3)
OPTLIQ	-0.27 (-5.21) ***	0.17 (0.68)	0.61 (2.40) **
DTURN	0.31 (0.15)	0.23 (0.11)	0.24 (0.11)
SIGMA	-1.32 (-4.11) ***	-1.22 (-3.74) ***	-1.39 (-4.22)
RET	0.37 (3.55) ***	0.41 (3.90) ***	0.40 (3.79) ***
SIZE	-0.80 (-3.06) ***	-0.32 (-1.07)	-0.63 (-2.19) ***
MB	9.40 (0.69)	8.38 (0.63)	8.80 (0.65)
LEV	1.46 (0.72)	0.46 (0.23)	1.05 (0.52)
ROA	0.36 (1.18)	0.54 (1.76) *	0.49 (1.60)
OPAQUE	0.92 (0.63)	1.48 (0.99)	1.02 (0.69)
SBAS	-0.18 (-1.62)	-0.25 (-2.26) **	-0.23 (-2.11) **
Constant	0.01 (0.04)	-0.10 (-0.26)	-0.26 (-0.68)
Observations	3076	3076	3076
R Squared	0.09	0.08	0.08
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Panel C: Crash Dummy (CRASH)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ	-0.59 (-5.41) ***	3.27 (6.71) ***	3.32 (6.88) ***
DTURN	2.80 (0.86)	2.31 (0.70)	2.73 (0.82)
SIGMA	-0.51 (-0.85)	-1.01 (-1.65) *	-1.36 (-2.20) **
RET	-0.14 (-0.63)	-0.13 (-0.60)	-0.13 (-0.63)
SIZE	-0.64 (-1.34)	-1.65 (-3.05) ***	-1.66 (-3.08) ***
MB	34.75 (2.38) **	33.21 (2.43) **	34.42 (2.56) **
LEV	4.44 (1.15)	5.38 (1.38)	5.97 (1.53)
ROA	0.60 (1.12)	0.86 (1.58)	0.73 (1.32)
OPAQUE	-3.30 (-1.02)	-4.77 (-1.46)	-5.02 (-1.55)
SBAS	0.34 (1.20)	0.21 (0.78)	0.28 (1.04)
Constant	-1.17 (-1.53)	-3.27 (-3.95) ***	-2.67 (-3.33) ***
Observations	3076	3076	3076
R Squared	0.05	0.06	0.06
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Note: This table shows for the coefficients and the t-statistics (in parentheses) of the regressions estimated over the sample period from 2000 to 2015. The dependent variables are 3 crash risk measures, negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH). ATM option liquidity measures are: OBAS is the log of option proportional bid-ask spread; OVOL is 0.1 times the log of option volume; OI is 0.1 times the log of open interest. OPTLIQ in the columns 1-3 represents OBAS, OI and OVOL, respectively. Other measures are the detrended monthly stock turnover, stock SIGMA, stock return, firm size, market-to-book ratio, leverage, return on assets, financial opaqueness, and stock proportional spread. Dturn is 0.01 times detrended monthly stock turnover. SIGMA is 10 times stock SIGMA. RET is 100 times stock return. MB is market-to-book ratio in basis point. Opaque is 0.1 times financial opaqueness. SIZE is 0.1 times firm size. Leverage is 0.1 times leverage. SBAS is 100 times stock proportional spread. The values of liquidity and other measures are lagged in one year. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables, respectively. The t-statistics are adjusted for clustering by firm and year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively. Their definitions and sources are reported in Appendix.

Table 9.9 Explaining Stock Price Crash Risk (ATM option)

9.5.3 Impacts During Periods of High Volatility

We investigate how the effects of option liquidity on crash risk vary when market volatility changes. These effects occur owing to volatility feedback effects and leverage effects. A main source of stock price crash risk is volatility feedback effects (French *et al*., 1987; Campbell and Hentschel, 1992), described as 'big price movements could cause investors to reassess market volatility and increase required risk premia. An increased risk premium reduces equilibrium prices, which reinforces the impact of bad news but offsets the impact of good news, thus generating negative skewness' (Hutton *et al*., 2009). Another perspective is related to leverage. As share prices decrease, an increase in firms' leverage comes with the falling value of equity. Consequently, greater volatility will be observed following this risky investment (Rathgeber *et al*., 2017). Hence, market volatility influences crash risk. We expect that market volatility will reinforce the role of option liquidity on stock price crash risk. For these reasons, the following hypothesis will be tested:

H_6: Option liquidity further increases stock price crash risk in the volatile market.

To reflect the quantity of crash risk and the degree of traders' risk aversion that determines the price of risk (Husted *et al*., 2018), we select the typical volatility measure, macroeconomic uncertainty index[62]. Macroeconomic uncertainty index is defined as the conditional volatility in parts of a large number of macroeconomic series that are purely unpredictable. This index typically increases during 'the periods of high unemployment, low output growth, and low economic activity' (Jurado *et al.*, 2015). Hence, we expect that liquidity will have a stronger effect on crash risk during periods of high uncertainty in financial markets and the economy.

In our paper, we define a dummy variable, *VOLDUM* which equals to 1 when the macroeconomic uncertainty index is higher than its yearly averaged value, and zero otherwise. Furthermore, we define three liquidity dummy variables *LIQDUM* (including *BASDUM*, *OIDUM* and *VOLDUM*) which equals to 1 when the option proportional spread is lower than its mean value, open interest and trading volume are higher than their mean value over the whole

[62] The data for the series for the period of January 2000 and August 2015 is obtained from Sydney Ludvigson's website (https://www.sydneyludvigson.com/macro-and-financial-uncertainty-indexes).

period, and zero otherwise. We conduct two-sample t-tests to analyse whether firms with high option liquidity are subject to greater stock price crash risk in the period of high macroeconomic uncertainty than other companies. In our analysis, if *VOLDUM* LIQDUM* equals to 1, firms are those with high option liquidity in volatile period. If *VOLDUM* LIQDUM* equals to 0, firms are those with low option liquidity in volatile period or those in the less volatile period.

Table 9.10 shows the effects of option market liquidity on stock price crash risk when uncertainty changes. If the probability of equality of variance test statistics is less than 0.05, we will select Satterthwaite t statistics. Otherwise, we use the pooled t-test. Panel A shows the result when *NCSKEW* is used as a crash risk measure. We observe that option liquidity remains important for crash risk. Importantly, firms with high option liquidity experience greater crash risk in volatile time than those in other situations. For instance, in Columns (1)-(2), the differences between NCSKEW in the two groups are significantly negative are at the 1% level. The differences also have negative values when the down-to-up volatility (*DUVOL*) and the crash dummy (*CRASH*) are used as the crash risk measures in Panel B and Panel C.

Panel A: Negative Skewness (NCSKEW)

OPTLIQ	VOLDUM* LIQDUM=0 (1)	VOLDUM* LIQDUM=1 (2)	DIFFERENCE (1)-(2)	EV TEST
OBAS	0.33	0.73	-0.39 (-4.98) ***	1.22 ***
OI	0.43	0.60	-0.17 (-2.11) **	1.01
OPTVOL	0.44	0.60	-0.16 (-2.03) **	1.01

Panel B: The Down-to-Up Volatility (DUVOL)

OPTLIQ	VOLDUM* LIQDUM=0 (1)	VOLDUM* LIQDUM=1 (2)	DIFFERENCE (1)-(2)	EV TEST
OBAS	0.01	0.19	-0.18 (-5.38) ***	1.13 ***
OI	0.05	0.13	-0.08 (-2.37) **	1.34 ***
OPTVOL	0.06	0.13	-0.07 (-2.06) **	1.36 ***

Panel C: Crash Dummy (CRASH)

OPTLIQ	VOLDUM* LIQDUM=0 (1)	VOLDUM* LIQDUM=1 (2)	DIFFERENCE (1)-(2)	EV TEST
OBAS	0.72	0.84	-0.12 (-10.22) ***	1.49 ***
OI	0.71	0.84	-0.13 (-10.84) ***	1.51 ***
OPTVOL	0.71	0.84	-0.13 (-10.62) ***	1.50 ***

Note: This table conducts the Pooled (or Satterthwaite) t-tests to compare the differences between three stock price crash risk measures, such as negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH), based on two groups from 2000 to2015. One group is that the interaction between VOLDUM and LIQDUM equals to 1 and another is that the interaction equals to 0. Three liquidity measures are OBAS, OI and OVOL. OBAS is the log of option proportional bid-ask spread; OVOL is 0.1 times the log of option volume; OI is 0.1 times the log of open interest. DIFFERENCE is the differences between these paired observations, such as VOLDUM* LIQDUM=1 and VOLDUM* LIQDUM=0. Pooled (or Satterthwaite) t-values are presented in parentheses. EV TEST is F test statistics of the equity of variances tests. If the probability of F test statistics is less than 0.05, it will indicate that variances are unequal. In this situation, we will select Satterthwaite t statistics. Otherwise, we use Pooled t test. This table shows the average value of crash risk measures and their differences based on two groups. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively. Their definitions and sources are reported in Appendix.

Table 9.10 Option Liquidity and Crash Risk During Periods of High Volatility

9.5.4 The Importance of Option Liquidity During the Financial Crisis

We turn our attention to the time variations of the relation between option market liquidity and stock price crash risk. An asset market crisis is defined as ‘a large price drops in response to a small shock to the economic environment’ (Yuan, 2005). An and Zhang (2013) provides empirical evidence that firms' exposure to crash risk is greater in the 2007-2008 financial crisis. In this part, we particularly focus on the dynamics between these variables during the financial crisis.

The argument of volatility feedback effects shows that whatever news comes, the market will respond in a volatile way. Generally, the released news leads to greater market volatility and higher risk premium. The relationship between the direct effect on the stock price and the risk premium effect will become negative if the nature of the news is good to the market. On the contrary, the above relationship is shown in positive if the news is bad. In short, the stock returns represent asymmetry (Cao *et al*., 2016). As the arrival of the financial crisis is bad news for the public, investors lose confidence and are afraid that such market turmoil accounts for a large part of historical crashes. Therefore, they will request an increased premium for crash risk (Habib and Hasan, 2017; Zhang *et al*., 2020). Contended by Hutton *et a*l. (2009), a significantly positive risk premium reinforces the effects of bad news but offsets the effects of good news, therefore producing negative skewness. For these reasons, the following hypothesis will be tested:

H_7: Option liquidity further increases stock price crash risk during financial crisis.

Therefore, we expect that option market liquidity will have bigger influences on crash risk during a crisis. Based on Duchin *et al. (*2010), we use a dummy variable, *CRIDUM*, which takes the value of 1 for the years of 2007 and zero, otherwise. Furthermore, we define three liquidity dummy variables *LIQDUM* (including *BASDUM, OIDUM* and *VOLDUM*) which equals to 1 when the option proportional spread is lower than its mean value, open interest and trading volume are higher than their mean value over the whole period, and zero otherwise. We conduct two-sample t-tests to analyse whether firms with high option liquidity are subject to greater stock price crash risk in a crisis than other companies. In our analysis, if *CRIDUM* LIQDUM* equals to 1, firms are those with high option liquidity in a crisis. If *CRIDUM* LIQDUM* equals to 0, firms are those with low option liquidity in crisis or those not in the crisis.

Table 9.11 shows that option liquidity has stronger impacts on stock price crash risk during the crisis. Panel A shows the result when NCSKEW is used as a crash risk measure. In Columns (1)-(2), the differences between NCSKEW in the two groups are significantly negative at the 1%

level. These results indicate more pronounced impacts of option liquidity on NCSKEW during the financial crisis. The differences also have negative values when the down-to-up volatility (DUVOL) and the crash dummy (CRASH) are used as the crash risk measures in Panel B and Panel C. Overall, consistent with the theoretical arguments put forth by Chang *et al*. (2017) and Hutton *et al*. (2009), option liquidity aggravates the severity of adverse selection problems and affects stock price crash risk, particularly during the financial crisis.

Panel A: Negative Skewness (NCSKEW)

OPTLIQ	CRIDUM* LIQDUM=0	CRIDUM* LIQDUM=1	DIFFERENCE	EV TEST
	(1)	(2)	(1)-(2)	
OBAS	0.54	1.08	-0.54 (-2.41) **	1.04
OI	0.54	0.88	-0.34 (-1.83) *	1.02
OPTVOL	0.54	0.88	-0.33 (-1.76) *	1.02

Panel B: The Down-to-Up Volatility (DUVOL)

OPTLIQ	CRIDUM* LIQDUM=0	CRIDUM* LIQDUM=1	DIFFERENCE	EV TEST
	(1)	(2)	(1)-(2)	
OBAS	0.10	0.36	-0.26 (-2.71) ***	1.12
OI	0.10	0.32	-0.22 (-2.74) ***	1.19
OPTVOL	0.10	0.32	-0.22 (-2.67) ***	1.16

Panel C: Crash Dummy (CRASH)

OPTLIQ	CRIDUM* LIQDUM=0	CRIDUM* LIQDUM=1	DIFFERENCE	EV TEST
	(1)	(2)	(1)-(2)	
OBAS	0.77	0.94	-0.17 (-8.49) ***	3.05 ***
OI	0.77	0.94	-0.17 (-10.09) ***	3.03 ***
OPTVOL	0.77	0.93	-0.17 (-9.44) ***	2.88 ***

Note: This table conducts the Pooled (or Satterthwaite) t-tests to compare the differences between three stock price crash risk measures, such as negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH), based on two groups from 2000 to 2015. One group is that the interaction between CRIDUM and LIQDUM equals to 1 and another is that the interaction equals to 0. Three liquidity measures are OBAS, OI and OVOL. OBAS is the log of option proportional bid-ask spread; OVOL is 0.1 times the log of option volume; OI is 0.1 times the log of open interest. DIFFERENCE is the differences between these paired observations, such as CRIDUM*LIQDUM=1 and CRIDUM*LIQDUM=0. Pooled (or Satterthwaite) t-values are presented in parentheses. EV TEST is F test statistics of the equity of variances tests. If the probability of F test statistics is less than 0.05, it will indicate that variances are unequal. In this situation, we will select Satterthwaite t statistics. Otherwise, we use Pooled t test. This table shows the average value of crash risk measures and their differences based on two groups. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively. Their definitions and sources are reported in Appendix.

Table 9.11 Option Liquidity and Stock Price Crash Risk in Financial Crisis

9.5.5 Controlling for Endogeneity

This part analyses the endogeneity problems in the relation between option market liquidity on stock price crash risk. Based on Chang *et al*. (2017), the findings may be subject to endogeneity problems because of omitted variables or reverse causality running from stock price crash risk to asset market liquidity. During the crash periods, the plunging stock prices cause funding constraints (Hameed *et al*., 2010). Funding liquidity tightness amplifies the market-wide liquidity dry-ups (Rösch and Kaserer, 2013). To control for this effect, we adopt an instrument variable (IV) approach and use the yearly average value of industry liquidity (IOPTLIQ) as the instrument for option liquidity. This variable is a valid instrument for firm-level option liquidity because firms in the same industry subject to similar risk. Meanwhile, individual option liquidity characteristics are unlikely to have significant impacts on the industry option liquidity. Therefore, the industry liquidity is more correlated with firm's liquidity in option market while remaining uncorrelated with the individual firm's crash risk[63].

In this analysis, we perform two-stage least squares (2SLS) regressions over the sample period. In the first stage, we regress the individual firm's option liquidity on the industry option liquidity and obtained the predicted values of the individual firm's option liquidity. In the second stage, we regress crash risk measures on the predicted firm option liquidity and the set of control variables.

Table 9.12 shows the empirical evidence of these models. For brevity, we do not present the results for the first stage regression. However, we observe significant and positive relation between individual firm option liquidity and industry option liquidity across all the firms. In all panels, Columns (1), (2), and (3) show the results by regressing Negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH) respectively on the predicted option liquidity and the control variables. The coefficients for option proportional spread are negative and significant. This result indicates that higher option liquidity increases crash risk. Results from columns (2) and (3) show that option interest and trading volume positively explain crash risk. These findings show that option liquidity significantly and positively affects stock price crash risk.

[63] We perform F-test on the instruments in the first stage for endogeneity, the null hypothesis is that there are weak instruments. If the p-value is smaller than 0.05, we will not accept the null, indicating that our instruments are not weak, which is good. The results show that industry option liquidity is a suitable instrument for individual firm option liquidity support the strong instruments.

Panel A: Negative Skewness (NCSKEW)

	OBAS (1)	OI (2)	OVOL (3)
OPTLIQ	-1.00 (-4.26) ***	1.27 (1.84) *	1.78 (2.38) **
DTURN	0.06 (0.02)	-0.90 (-0.27)	-0.72 (-0.22)
SIGMA	-3.53 (-7.10) ***	-3.46 (-6.48) ***	-3.75 (-6.61) ***
RET	1.19 (7.12) ***	1.25 (7.13) ***	1.27 (7.28) ***
SIZE	-2.32 (-4.31) ***	-1.88 (-2.51) **	-2.25 (-2.99) ***
MB	-0.30 (-0.22)	-0.75 (-0.56)	-0.91 (-0.71)
LEV	2.13 (0.70)	1.51 (0.47)	2.42 (0.75)
ROA	0.68 (1.29)	1.03 (1.98) **	0.90 (1.71) *
OPAQUE	-0.02 (-0.02)	0.22 (0.19)	0.02 (0.02)
SBAS	-0.50 (-3.24) ***	-0.70 (-4.59) ***	-0.65 (-4.21) ***
Constant	0.57 (0.83)	0.12 (0.15)	0.12 (0.15)
Observations	5087	5087	5087
R Squared	0.06	0.05	0.05
Year FE	YES	YES	YES
Industry FE	YES	YES	YES
Weak Instruments	141.11 ***	211.43 ***	206.24 ***

Panel B: The Down-to-Up Volatility (DUVOL)

	OBAS	OI	OVOL
	(1)	(2)	(3)
OPTLIQ	-0.39 (-3.82) ***	0.30 (0.97)	0.55 (1.65)
DTURN	0.33 (0.22)	-0.08 (-0.05)	-0.01 (-0.01)
SIGMA	-1.48 (-6.91) ***	-1.39 (-6.06) ***	-1.51 (-6.18) ***
RET	0.47 (6.15) ***	0.48 (6.06) ***	0.49 (6.24) ***
SIZE	-0.79 (-3.37) ***	-0.43 (-1.28)	-0.62 (-1.87) *
MB	0.53 (0.62)	0.44 (0.50)	0.35 (0.42)
LEV	1.22 (0.89)	0.62 (0.43)	1.06 (0.72)
ROA	0.52 (2.32) **	0.68 (3.08) ***	0.63 (2.81) ***
OPAQUE	0.09 (0.17)	0.30 (0.54)	0.19 (0.35)
SBAS	-0.20 (-2.81) ***	-0.28 (-4.10) ***	-0.27 (-3.78) ***
Constant	0.02 (0.04)	-0.05 (-0.11)	-0.10 (-0.24)
Observations	5087	5087	5087
R Squared	0.06	0.05	0.05
Year FE	YES	YES	YES
Industry FE	YES	YES	YES
Weak Instruments	141.11 ***	211.43 ***	206.24 ***

Panel C: Crash Dummy (CRASH)

	OBAS	OI	OVOL
	(1)	(2)	(3)
OPTLIQ	-0.19 (-5.45) ***	0.64 (6.13) ***	0.73 (6.71) ***
DTURN	0.98 (2.11) **	0.87 (1.93) *	0.91 (2.04) **
SIGMA	-0.12 (-1.47)	-0.22 (-2.67) ***	-0.31 (-3.48) ***
RET	0.03 (1.08)	0.07 (2.17) **	0.07 (2.23) **
SIZE	-0.15 (-1.94) *	-0.44 (-3.97) ***	-0.48 (-4.40) ***
MB	0.95 (4.04) ***	0.70 (4.58) ***	0.69 (4.70) ***
LEV	-0.04 (-0.09)	0.55 (1.09)	0.70 (1.38)
ROA	0.19 (2.67) ***	0.21 (2.98) ***	0.18 (2.43) **
OPAQUE	-0.07 (-0.27)	-0.26 (-0.97)	-0.27 (-1)
SBAS	-0.02 (-0.69)	-0.04 (-1.37)	-0.02 (-0.86)
Constant	0.47 (4.36) ***	0.15 (1.25)	0.22 (1.92) *
Observations	5087	5087	5087
R Squared	0.05	0.06	0.06
Year FE	YES	YES	YES
Industry FE	YES	YES	YES
Weak Instruments	141.11 ***	211.43 ***	206.24 ***

Note: This table shows for the coefficients and the t-statistics (in parentheses) of the regressions estimated over the sample period from 2000 to 2015. The dependent variables are 3 crash risk measures, negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH). Option liquidity measures are: OBAS is the log of option proportional bid-ask spread; OVOL is 0.1 times the log of option volume; OI is 0.1 times the log of open interest. OPTLIQ in the columns 1-3 represents OBAS, OI and OVOL, respectively. Other measures are the detrended monthly stock turnover, stock SIGMA, stock return, firm size, market-to-book ratio, leverage, return on assets, financial opaqueness, and stock proportional spread. Dturn is 0.01 times detrended monthly stock turnover. SIGMA is 10 times stock SIGMA. RET is 100 times stock return. MB is market-to-book ratio in basis point. Opaque is 0.1 times financial opaqueness. SIZE is 0.1 times firm size. Leverage is 0.1 times leverage. SBAS is 100 times stock proportional spread. The values of liquidity and other measures are lagged in one year. Observations are the number of firm-year observations. Year FE and Industry FE are the year and industry dummy variables, respectively. The t-statistics are adjusted for clustering by firm and year. Weak Instruments is the F-test statistics on the instruments in the first stage. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively. Their definitions and sources are reported in Appendix.

Table 9.12 Endogeneity Analysis

9.6 Conclusion

This study examines the importance of option liquidity on stock price crash risk over a large cross section of U.S. companies between 2000 and 2015. This study presented tests for the seven hypotheses developed to provide findings for the empirical research. Table 8.8 presents a summary of the hypothesis testing results and the obtained story, respectively.

Hypothesis	Expected Effect	Result	Obtained Sign
H_1	Option liquidity decreases stock price crash risk	Not	
H_2	Option liquidity increases stock price crash risk.	Supported	+
H_3	Option liquidity further increases stock price crash risk in the firms with high information asymmetry.	Supported	+
H_4	Option liquidity further increases stock price crash risk in the firms with a large level of short interests.	Supported	+
H_5	Option liquidity further increases stock price crash risk in the firms with high option trader sentiment.	Supported	+
H_6	Option liquidity further increases stock price crash risk in the volatile market.	Supported	+
H_7	Option liquidity further increases stock price crash risk during financial crisis.	Supported	+

Note: This table summarizes the hypothesis test results. The columns of variable show hypothesis number, expected results, empirical results and obtained sign. Column of empirical results includes support hypothesis (Supported) and not support hypothesis (Not). Column of obtained sign includes positive effect (+).

Table 9. 13 Summary of the Hypothesis Testing Results

The findings show that option liquidity is positively related to stock price crash risk. In consistent with the short-termism theory and governance theory (blockholder exit mechanism), option market liquidity amplifies crash risk through the greater irrational investment from uninformed investors and larger selling pressure coming from the large blockholder exists (Edmans, 2009; Bhatia *et al*., 2014). Empirically, companies with higher option liquidity experience lower bid-ask spread, higher trading volume or greater open interests for their stock options in the secondary markets. Besides these, the relation is stronger for companies with higher insider trading, a higher probability of informed trading, larger short interest, or during a financial crisis. These findings reinforce the notion that investors focus more on the collapses of stock price due to volatility feedback effects and leverage effects, especially during periods of greater volatility in financial markets.

In essence, this paper contributes to the existing literature on stock price crash risk. As the outbreaks of the global financial crisis and Covid-19 pandemic underline the severity of stock price crash risk (Vo, 2020; Mazur *et al*., 2021), understanding the extreme return distribution improves investors' portfolio diversification and their risk management strategies (Chauhan *et al*., 2017). It informs them to take corrective action after considering extremely catastrophic consequences (Kim *et al*., 2011b). Xu *et al.* (2013) states that investors, regulators, and policy makers are seriously concerned about the influencing factors of crash risk. Previous studies have provided mounting findings on the determinants of stock price crash risk (Habib *et al*., 2018). Our paper is the first to document the link between the liquidity of financial options to crashes as well as other established determinants in the literature. We display a new channel to reduce and even prevent extreme and sudden stock downturns through reducing equity option liquidity, and hence help traders to invest in the less risky businesses (Habib and Hasan, 2017).

9.7 Appendix

9.7.1 Appendix A: Variable Definitions

The data sources are CRSP and Compustat and website unless specified otherwise. Data item codes are in italics.

Panel A: Stock Price Crash Risk Definition

Variable	**Definition**
Firm-Specific Daily Returns	This paper estimates firm-specific daily returns from an expanded market and industry index model regression for each firm and year (Hutton *et al*., 2009). $r_{j,t} = \alpha_i + \beta_{1,j} * r_{m,t-1} + \beta_{2,j} * r_{i,t-1} + \beta_{3,j} * r_{m,t} + \beta_{4,j} * r_{i,t} + \beta_{5,j} * r_{m,t+1} + \beta_{6,j} * r_{i,t+1} + \varepsilon_{j,t}$; where $r_{j,t}$ is the return on stock j in day t, $r_{m,t}$ is the return on the CRSP value weighted market index in day t, and $r_{i,t}$ is the return on the Fama-French value-weighted 48 industry index. The firm-specific daily return is the natural log of one plus the residual return from the regression model.
NCSKEW	NCSKEW is the negative coefficient of skewness of firm-specific daily returns. It is the negative of the third moment of each stock's firm-specific daily returns, divided by the cubed standard deviation.
DUVOL	DUVOL is the log of the ratio of the standard deviation of firm-specific daily returns for the ‘‘down-day” sample to standard deviation of firm-specific daily returns for the ‘‘up-day” sample over the fiscal year. For any stock j over a one-year period, this paper separates all the days with firm-specific daily returns above (below) the mean of the period and call this the ‘‘up” (‘‘down”) sample.
CRASH	The crash dummy (CRASH) is defined as a dummy variable equal to 1 if there are one or more weekly returns falling 3.09 standard deviations below the mean daily returns over the fiscal year, and 0 otherwise.

Panel B: Option Liquidity Definition

Variable	**Definition**
OBAS	Option proportional bid-ask spread is calculated as the average value of the daily difference between ask and bid quotes, divided by their mid-quote over fiscal year.
OI	Option open interest is the sum of daily option open interest over fiscal year and then takes the natural log transformation.
OVOL	Option trading volume is the sum of daily option trading volume over fiscal year and then takes the natural log transformation.

Panel C: Other Variable Definition

Variable	Definition
DTURN	The detrended monthly stock turnover is calculated as the difference between average monthly turnover over fiscal year and the prior fiscal year's average monthly turnover.
SIGMA	SIGMA is the standard deviation of the firm-specific daily return over fiscal year.
RET	RET is the average firm-specific daily return over fiscal year.
SIZE	SIZE is the natural logarithm of book value of total assets (*AT*).
MB	Market-to-book ratio is calculated as the market value of equity (*PRCC F*×*CSHO*) divided by the book value of equity (*CEQ*).
LEV	Leverage is the Ratio of long-term debt (*DLTT*) over the book value of total assets (*AT*).
ROA	Return on assets is the ratio of income before extraordinary items (O*IBDP*) over book value of total assets (*AT*).
SBAS	Stock proportional spread is the average value of daily quoted bid-ask spread scaled by the midpoint of the bid and ask prices over fiscal year.
PIN	PIN is a measure of the probability of informed trading. The data source of annual PIN measure from 1996 to 2010 is available at: http://scholar.rhsmith.umd.edu/sbrown/pin-data?destination=node/998.
SENTIMENT	Investor sentiment is the put to call volume ratio.
SHORT	Short interest ratio is calculated as the number of shares sold short divided by total shares outstanding from the last month of the fiscal year (*SHROUT* is expressed in units of a thousand shares in CRSP).
INSIDER	The degree of insider trading is the yearly ratio of the total number of shares traded by insiders (namely, executive directors) and the total number of shares outstanding for firms (*SHROUT* is expressed in units of a thousand shares in CRSP).

OPAQUE	Based on Fang *et.al* (2016), performance-matched discretionary accruals in fiscal year t, is calculated as a firm's discretionary accruals minus the corresponding discretionary accruals of a matched firm from the same fiscal year and 1-digit SIC industry with the closest return on assets. A firm's discretionary accruals are defined as the difference between its total accruals and the fitted normal accruals derived from a modified Jones model (Jones, 1991). The modified Jones model follows Dechow *et. al* (1995) and is specified as $\frac{TA_{i,t}}{ASSET_{i,t-1}} = \beta_0 + \beta_1 * \frac{1}{ASSET_{i.t-1}} + \beta_2 * \frac{\Delta REV_{i,t}}{ASSET_{i.t-1}} + \beta_3 * \frac{PPE_{i,t}}{ASSET_{i.t-1}} + \varepsilon_{i,t}$; Total accruals $TA_{i,t}$ are defined as earnings before extraordinary items and discontinued operations (*IBC*) minus operating cash flows (*OANCF−XIDOC*), $ASSET_{i.t-1}$ is total assets at the beginning of year t (*AT*), $\Delta REV_{i,t}$ is the change in sales revenue (*SALE*) from the preceding year, and $PPE_{i,t}$ is gross property, plant, and equipment (*PPEGT*). The fitted normal accruals are computed as $NA_{i,t} = \widehat{\beta_0} + \widehat{\beta_1} * \frac{1}{ASSET_{i.t-1}} + \widehat{\beta_2} * \frac{(\Delta REV_{i,t} - \Delta AR_{i,t})}{ASSET_{i.t-1}} + \widehat{\beta_3} * \frac{PPE_{i,t}}{ASSET_{i.t-1}}$ with the change in accounts receivable (*RECT*) subtracted from the change in sales revenue (*SALE*). Firm-year specific discretionary accruals are calculated as $DA_{i,t} = \frac{TA_{i,t}}{ASSET_{i,t-1}} - NA_{i,t}$. The measure of opacity $OPAQUE_{i,t}$ in financial reports is the prior three-year moving sum of the absolute value of annual discretionary accruals, where discretionary accrual is estimated from the modified Jones model (Dechow *et. al*, 1995; Hutton *et al.*, 2009): $OPAQUE_{i,t} = AbsV(DA_{i,t-1}) + AbsV(DA_{i,t-2}) + AbsV(DA_{i,t-3})$;

Table 9.14 Variable Definitions

9.7.2 Appendix B: Correlation Matrix

	NCSKEW	DUVOL	CRASH	OBAS	OI	OVOL	DTURN	SIGMA	RET	SIZE	MB	LEV	ROA	OPAQUE	SBAS
NCSKEW	1														
DUVOL	0.92	1													
CRASH	0.48	0.55	1												
OBAS	-0.21	-0.18	-0.32	1											
OI	0.15	0.13	0.34	-0.77	1										
OVOL	0.17	0.14	0.34	-0.80	0.99	1									
DTURN	-0.02	-0.01	0.08	-0.06	0.17	0.16	1								
SIGMA	-0.07	-0.06	-0.02	0.11	-0.12	-0.08	0.08	1							
RET	0.02	0.03	-0.08	0.11	-0.21	-0.19	-0.11	0.23	1						
SIZE	0.05	0.08	0.13	-0.47	0.56	0.53	0.26	-0.39	-0.18	1					
MB	-0.02	-0.01	-0.0002	0.02	-0.002	-0.01	-0.01	0.02	0.02	-0.06	1				
LEV	-0.04	-0.02	-0.05	0.10	-0.05	-0.07	0.17	-0.09	-0.02	0.21	0.10	1			
ROA	0.16	0.16	0.10	-0.08	-0.005	-0.004	-0.04	-0.48	-0.05	0.02	0.02	-0.12	1		
OPAQUE	0.01	-0.004	-0.01	0.03	-0.01	0.01	-0.13	0.38	-0.02	-0.32	0.03	-0.11	-0.23	1	
SBAS	0.09	0.11	0.02	0.02	0.04	0.02	0.05	0.24	0.03	0.03	0.01	-0.01	-0.04	0.09	1

Notes: This table shows the unconditional, pair-wise correlations of crash risk measures, and option liquidity from 2000 to 2015. These measures are the yearly firm-level measures Stock price crash risk measures are negative skewness (NCKSEW), the down-to-up volatility (DUVOL) and the crash dummy (CRASH). Option liquidity measures are: OBAS is the log of the yearly averaged option proportional bid-ask spread; OVOL is the log of option volume; OI is the log of open interest. Other vairables are DTURN, SIGMA, RET, SIZE, MB, LEV, ROA, OPAQUE and SBAS The values of option liquidity are lagged in one year. *, **, *** indicate the significance at 10%, 5%, and 1% level, respectively.

Table 9. 15 Correlation Matrix of Crash Risk, Option Liquidity and Other Variables

Chapter 10 Conclusion

This is the final chapter of my thesis, and the major purpose of this chapter is to summarise the evidence obtained from earlier chapters, regarding the role of excess cash in equity option liquidity, stock and equity option liquidity linkage, as well as the effects of equity option liquidity on stock price crash risk. Subsequently, this chapter will discuss how the findings contribute to policies for equity option liquidity. Finally, this section points out several limitations to this thesis and provides some suggestions for further research.

10.1 Summary of Findings

10.1.1 Excess Cash and Equity Option Liquidity

Mounting literature focused on different determining factors of option market liquidity, such as asymmetric information, inventory risk and stock market movements (Pan and Poteshman, 2006; Cao and Wei, 2010; Li, 2016). We explored a new determinant of equity option market liquidity that is excess cash. Excess cash is the cash reserve in excess of that at a normal operating level, which incorporates information about firm prospects (Simutin, 2010) and is easily wasted by entrenched managers (Harford *et al*., 2008). Our study examined the effects of excess cash on equity option liquidity in the US market during 2005 and 2015.

Two competing theoretical hypotheses are proposed to explain the association between excess cash and asset market liquidity. According to the pecking order theory, because of the reduced adverse selection problems from the uncertainty in asset value, larger excess cash enhances asset market liquidity (Gopalan *et al*., 2012; Huang and Mazouz, 2018). In contrast, consistent with the agency theory, larger excess cash lowers asset market liquidity (Gopalan *et al*., 2012; Huang and Mazouz, 2018). As the negative investment prospects and larger agency conflicts raise excess cash, market liquidity decreases with larger excess cash when investors seek solutions to these problems.

We investigated the relationships between excess corporate cash holding and equity option market liquidity. The findings showed that option trading volume and open interests increase in cash-rich companies while the proportional bid-ask spreads decrease in excess cash. In other words, excess cash improves market liquidity, which supports the previous hypothesis, as larger excess cash lessens asymmetric information problems arising from the uncertainty in firm valuations and thereby increases option market liquidity (Gopalan *et al.*, 2012). The relationship between excess cash and equity option market liquidity is more pronounced for firms with higher informed trading or during periods of high volatility in financial markets. Therefore, we exhibit a new supply-side source to explain option market liquidity: excess cash.

10.1.2 Stock and Equity Option Liquidity Linkage

As excess cash is a common determinant of stock and option liquidity, we wonder whether there is an interaction between stock and option liquidity. Apart from excess cash, the liquidity of the underlying stocks is also a driver of option liquidity (Cho and Engle, 1999; Muravyev and Pearson, 2020). We turn to examine the linkage of the stock and equity option markets liquidity in US from 2004 to 2015. There are three mechanisms to support this linkage, which are funding mechanism, hedging mechanism and option-induced demand mechanism. Firstly, on the supply side, tighter funding constraint and greater volatility risk causes market liquidity reduction and creates a disaster of asset fire-sale, thus increasing multiple asset market liquidity linkages (Brunnermeier and Pederson, 2009). Secondly, in the hedging mechanism, illiquid options with greater inventory risk increase the propensity to hedge in the underlying market, thereby resulting in the significant liquidity spillover effect from the underlying stocks to the equity options (Li, 2016). Furthermore, because of the higher level of asymmetric information, the possible and convenient option-equity arbitrage (such as large option mispricing and high hedge costs) increases stock and equity option market illiquidity (Huh *et al*., 2015). Lastly, we explore the option-induced demand mechanism of liquidity linkages across different asset classes. According to the demand-based pricing theory (Garleanu *et al*., 2009), there is no perfect option hedge. Under the demand pressures from the uncertainty of the option unhedgeable part, both inventory risk and adverse-selection risk increase trading costs and option demand pressure, which causes market liquidity linkages (Korn *et al*, 2019; Goyenko *et al.*, 2015).

In the empirical analysis, we performed primary component analysis to construct the stock liquidity measure based on the proportional bid-ask spread and Amihud illiquidity ratio, as well as option liquidity measures based on the option proportional spread and implied volatility spread. Firstly, we use Vector-Autoregressive analysis to investigate whether stock and equity option market liquidity is positively related. Subsequently, we examined whether the funding liquidity, inventory risk and asymmetric information can explain stock-equity option liquidity linkages. The overall evidence showed that funding liquidity is a liquidity supplier of stock-equity option market liquidity linkages. Option market illiquidity is positively linked to the underlying stock market illiquidity at all the firm, portfolio, and market levels. Liquidity linkage is inversely associated with firm size, short-selling interests, and the PIN measures. Larger size firms and firms with a higher level of short-selling and greater information asymmetric risks will display less significant liquidity interactions across stocks and equity options.

10.1.3 Equity Option Liquidity and Stock Price Crash Risk

In addition to the determining factors, we also explore the consequence of option market liquidity, such as stock price crash risk. Our study explored the effects of option market liquidity on crash risk. In line with the negative information hoarding argument, the accumulation of negative news causes a sustained rise in price and keeps price inflation. Beyond breaking point, the bad information will be conveyed to the market in a short time and hence causes the stock price plunge (Bhatia *et al*., 2014). The phenomenon of extreme and sudden negative firm-specific stock returns refers to stock market crash risk (Liu and Zhong, 2018).

Two hypotheses in opposing directions used to explain the relation between asset market liquidity and stock price crash risk are developed. Along with the corporate government (external monitoring mechanism) and information production efficiency perspectives, market liquidity exerts negative effects on crash risk by reducing adverse information hoarding activities of managers (Edmans, 2009; Holden *et al*., 2014). In contrast, in line with the short-termism theory and governance theory (blockholder exit mechanism), market liquidity amplifies crash risk through the greater irrational investment from uninformed investors and larger selling pressure coming from the large blockholder exists (Edmans, 2009; Bhatia *et al*., 2014).

Our empirical evidence indicated that US equity option market liquidity is positively related to stock price crash risk from 2000 to 2015. The magnitude of crash risk will increase in the conditions of firms with a higher option trading volume and open interests, as well as decreasing option bid-ask spread. This relation is more significant when firms face a greater degree of informed trading, larger short interests, and option trader sentiment or during periods of high volatility in financial markets.

My thesis made several contributions to the development of academic literature. To the best of my knowledge, we are the first research to fill some gaps in the derivative literature. Firstly, we showed that excess cash is a newly discovered determinant of derivatives market liquidity, such as equity options. Excess cash is positively related to equity option market liquidity. Secondly, we proved the positive time-varying dynamics of underlying stock and equity option market liquidity interactions and explained the supply- and demand-sided sources of their linkages. Thirdly, we indicated that equity option liquidity positively affects crash risk in the underlying equity market.

10.2 Policy Implications

For practical significance, our research makes implications for the design of the regulators' policy making and traders' investment strategies.

10.2.1 Broaden the Sources of Funding

A political warning from recent news highlights that regulators need to solve the shortage of funding sources. For instance, the Bank of England (2020) reports that sufficient corporate cash reserves, enhance asset market liquidity and retain financial stability, which provides political implications to regulators. Furthermore, Bloomberg (2020) also shows that the attention of market participants is drawn into the association between corporate cash reserves and input resources that understand their nature.

These kinds of news encourage us to explore new funding sources to promote option market liquidity. Excess cash, the level of cash reserve in excess of that at the normal operating level, embeds the information about firm prospects (Simutin, 2010). It is crucial to raise excess cash to develop firms' risk-management capabilities. Large excess cash can reduce adverse selection problems from the uncertainty in asset value, thereby facilitating option market liquidity. Thus, excess cash is a vital capital source for option market liquidity. There are some implications for policy makers, government, and companies. Firstly, policy makers could formulate and implement the policies that could increase the amount of excess cash in the firms. Secondly, the government could also work on raising the traders' awareness of excess cash, thereby encouraging individuals, institutions, and public investors to invest in the firms which hold sufficient excess cash. Thirdly, companies could hold large excess cash to efficiently deploy scarce funding resources and address emerging crises when risks do materialize.

10.2.2 Build More Diversified Portfolios

Diversification could be achieved by investing in different asset classes, such as stock and equity options. We closely monitor the interaction between stock and equity option market liquidity, especially when these asset markets are characterized by the common fundamentals and hedging connections (Marra, 2016). A profound grasp of stock-equity option liquidity transmission benefits to building more diversified portfolios, which could reduce investors' overall level of volatility and potential risk. For example, regulators' policymaking and traders' investment strategies could involve this approach to reduce the losses from financial disasters by predicting and even preventing liquidity withdraws.

What is more, as the outbreaks of the global financial crisis and the Covid-19 pandemic underline the consequence of stock price crash risk (Vo, 2020; Mazur *et al.,* 2021), understanding the extreme return distribution improves investors' portfolio diversification. We present a new channel to reduce and even prevent extreme stock declines via enhancing equity option liquidity, thus providing investors with guidance to allocate capital resources to less risky businesses (Habib and Hasan, 2017). When investments in stocks perform poorly, other investments in options in the portfolio may offset losses and even open up opportunities for additional profit-making.

10.2.3 Develop the Risk Management Tools

Our research on stock and equity option liquidity linkages provides some implications for financial intermediaries, investors, and regulators. Firstly, financial intermediaries could develop more complicated risk management tools to allocate financial resources and eliminate exposures from multiple asset markets. Secondly, investors and regulators have a deeper understanding of the effects of new trading regulations and changes in (equity option) market structures on multiple asset markets.

Furthermore, understanding the extreme return distribution also improves investors' risk management strategies (Chauhan *et al*., 2017). It guides them to take corrective action after considering extremely catastrophic consequences (Kim *et al*., 2011b).

10.3 Limitations and Suggestions for Future Research

10.3.1 Limitations

There are also some limitations to this chapter. Firstly, owing to the lack of data availability, this thesis confronts several weaknesses in measuring firm-specific investors' sentiment. For example, we cannot obtain buy and sell volumes to create a buy-sell imbalance for an individual stock, which reflects the change in investor sentiment (Fu *et al.*, 2020).

Secondly, regarding the limitation of transaction costs, such as the difference in lending and borrowing rates, taxes, and margin requirements, this study fails to take these different types of transaction costs into account fully.

Thirdly, as our research focused on equity option liquidity, we followed previous literature (see Cao and Wei, 2010; Hameed *et al*., 2010; Wei and Zheng, 2010; An and Zhang, 2013; Chan *et al*., 2013; Asem and Alam, 2014; Byun and Kim, 2016; Kaul and Kayacetin, 2017) to select sample data to best represent the U.S. equity markets. The removal of small-size companies and financial companies is to avoid the idiosyncrasies related to these companies. Even we only used sample data of the public-listed companies with the options on underlying stocks, the outcome of the research is less biased because we did not consider the extreme data.

10.3.2 Suggestions for Future Research

The following recommendations are suggested for future study. Firstly, this study only chooses funding liquidity, trader sentiment, short interest, insider trading, a probability of informed trading, market volatility indices and financial crisis as the main factors to research. Other factors could affect the results of our studies, such as trading exchanges, trading regulations, market structures, investor classifications, transaction technology, and covid-19. Therefore, in the future, it would be worth considering whether to add those potential factors to the current research to make the results more perfect.

Secondly, a future study could identify different internet search queries that contribute to market liquidity, because the search queries could qualify as an excellent proxy for the retail investors' attention to stock markets (Dimpfl and Jank 2016). It may use a qualitative research direction in conjunction with a quantitative one to arrive at clearer research findings.

Thirdly, a future study could further investigate the sampling country US with other countries because asset markets in the different countries may affect our research quality outcome in a global context.

Fourthly, a future study could examine other derivative instruments, which also account for a significant portion of the trade market, such as European option markets, CDS markets and future markets.

Chapter 11 Reference

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